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CONTENTS

ANALYSIS OF SHIP TARGETING SYSTEMS USED IN PSC REGIMES

Ozcan Arslan[1], Onder Eyigun[2]

[1]*Maritime Transportation and Management Engineering Department, ITU Maritime Faculty, Turkey*
[2] *Ministry of Transportation, Maritime and Communication, Turkey*

ABSTRACT

Ships are the most intensively controlled vehicles in the world. Ships are controlled and inspected by a number of corporations and mechanisms. These can be beneficiary and directly in contact with the vessel or third party organisations. Basically, owner, operator, charterer, cargo owner are beneficiary corporations for the vessels. Institutions like flag state, classification society, P&I insurer are also directly in contact with the vessel. Port State Control (PSC) is one of the most significant mechanism and best example for "third party inspections".

The most significant handicap in PSC is the limited number of human resources (PSCO's) in comparison with the ships to be inspected in particular regions. PSC regimes are using different targeting systems and this sometimes cause inconsistent results among diffent regimes and discussions have been made accordingly.

In this study, PSC regimes and their historical backgrounds are introduced and explanatory information is given about ship targeting systems used in some of these regimes. Also a questionnaire is prepared and applied to the inspectors of different PSC regimes for the purpose of determining necessity, effectiveness and borders of the targeting systems. Results are analysed in SPSS programme and evaluations, comments made for improving, upgrading and harmonization of ship targeting systems.

Keywords: *Safety, Maritime, Ship, PSC, Inspection.*

1. INTRODUCTION

Being the most important vehicle of maritime transportation, vessels are inspected by several organizations and institutions. It is primarily under the responsibility of Flag States to ensure that vessels meet the requirements of international conventions. However, particularly due to ship-owners' preference to use flags of convenience in the last three decades, the effectiveness of Flag States in the world fleet has decreased.

In consequence of the tanker accidents experienced in the 1960s and the 1970s (Torrey Canyon in 1967 and Amoco Cadiz in 1978) and the severe oil pollution these accidents caused in the British and French coasts, European countries called for the vessels in their region to be controlled and inspected more strictly and the first PSC regime was established with the issuance of the "Paris MOU" by 14 European states. Today there is a total of 10 PSC regimes, including the USCG inspections carried out in the United States of America, and the number of the countries that take part in these conventions is 128 [1].

In all regional PSC memorandums (MOU), the numbers of Port State Control Officers (PSCO), or the personnel that will carry out inspections, are inadequate in consideration of the number of vessels to be inspected. Due to this reason, certain targeted inspection rates are set forth in PSC regimes. For instance, while the Paris MOU initially required that 25% of the vessels calling the related ports to be inspected, in Tokyo MOU this rate was stipulated to be 50%, which later on was increased to 75% in 1996 [2]. In addition, in order to ensure that the inspections are conducted in a more effective and meaningful manner, risk-based "vessel targeting systems" are used for selecting the vessels to be inspected. With the "targeting factors" employed in many PSC organizations, vessels are scored on the basis of varying criteria. The purpose in these systems is to determine to which risk group a particular vessel belongs among the risk groups of low, medium and high, and to ensure that the inspections of vessels bearing high level are more prioritized and carried out more frequently.

The purpose of the present study is to set forth the similarities and differences among the vessel targeting systems used in some Port State Control (PSC) regimes, to determine the more prominent parameters and to make suggestions and recommendations on the parameters that need to be included in targeting systems for establishing a more effective PSC inspection mechanism.

Within the scope of the study questionnaire method was used, and the officers working in PSC regimes were asked to fill in a questionnaire. In the preparation of the questionnaire the common aspects of present targeting systems were taken into consideration, items concerning the factors needed to establish a more effective system were prepared and the questionnaire was conducted on inspectors working in PSC regimes. Questionnaire data were evaluated by means of the SPSS statistical software, and then analyzed and interpreted.

The present study offers a new perspective to the matter, since it reflects the opinions of the Port State Control officers that perform inspections under different PSC regimes, and therefore has the quality to guide future studies to be conduct on this field.

2. MARITIME SAFETY AND PORT STATE CONTROL SYSTEM

Maritime industry can be called as 'safety sensitive' industry when compared with other industries. Ships are subject for many different types of hazards. For minimizing risks on board, ships are inspected by different mechanisms. There are several studies about maritime safety in the literature. Arslan and Er applied SWOT analysis methodology for understanding the positive and negative factors that affects safety of ship [3]. Knapp et al. evaluated ship inspections by cost/benefit analysis angle [4]. Heij et al. analyzed ship inspections by environmental focus [5]. Hänninen and Kujala analyzed inspection results by utilizing Bayesian network modeling approach [6].

The primary factors that are taken into consideration while performing maritime risk assessment are ship accidents, the resulting losses of life and property and possible environmental pollution. As a matter of fact the incident that led to the establishment of IMO and the issuance of many international conventions is the Titanic disaster of 1912. In the following periods, vessel accidents that resulted in loss of lives and severe marine pollution resulted in the establishment of new rules and regulations. On the other hand, the "Amoco Cadiz" disaster of 1978, which resulted in a 223,000 ton oil spill in European shores, became a factor that expedited the establishment of the Port State Control system.

Since vessels that are considered to be the core element of marine transportation are subjected to several hazards due to factors such as intense traffic on a certain area, structural causes, technical complexity, types of cargoes being transported and the weather and environmental conditions, performing risk assessment is inevitable.

Today, not only the vessels, but also their owners and managers may be evaluated to be of substandard. In order to improve safety and decrease the number of accidents in seafaring, inspections of substandard vessels are highly important.

Convenient flag implementations that did not have any significant place within the world merchant fleet expect for Liberia in the 1960s and the 1970s, started a rapid increase in the 1980s with the initial involvement of Panama, later on followed by countries such as Malta, the Bahamas and Marshall Islands.

With the ship-owners' increasing preference of using convenient flags the effect of flag states on their vessels started to decrease and the number of substandard vessels increased. It is considered that there is a relation between the use of convenient flags and the frequency of marine accidents [7]. The most significant indicators in accident investigations are vessel age and type. In studies conducted on these indicators examined the relation between vessels' age and maritime accidents caused by the structural deformations and machinery breakdowns of vessels [8], Pronce compared accidents that resulted in the total loss of vessels with vessels' ages and registries [9], and Thyregod and Nielsen (1993) examined the effect of vessels' ages on annual accident rates [10].

Port State Control (PSC) is the control carried out by a state to ensure that the status and equipment of a foreign-flagged vessel calling one of the ports of the mentioned state meet the criteria set forth in international conventions and that the personnel and the management of the said vessel comply with the applicable laws [11].

Besides of being accepted by IMO as the indicator of safety standard of the world's maritime fleet, accident statistics also enable evaluations on the effectiveness levels of PSC regimes. In addition, in the selection of vessels to be subjected to inspections by the United States Coast Guard (USCG) the accident history of a given vessel is considered as a major criterion and results in the vessel to be given a higher risk score.

PSC is the control implemented by a state on foreign vessels conducting international navigation to or from a port of the state concerning whether the vessels comply with international convention and the national legislation on safety at sea, protection of marine environment and living and working conditions on board, and the sanctions brought upon those vessels that do not comply to these [12]. Due to the failure of flag states in fulfilling their responsibilities substandard vessels conduct marine transportation and create risk factors in terms of marine safety. This is the point that led to PSC, which became one of the important components of safety in maritime transportation.

Currently, there are a total of 9 regional Port State Control Memorandums throughout the world. These are:

- Paris MOU (covering Europe and North Atlantic)
- Tokyo MOU (covering Asia and the Pacific)
- Acuerdo de Vina del Mar (covering Latin America)
- Caribbean MOU
- Abuja MOU (covering West and Central Africa)
- Black Sea MOU
- Mediterranean MOU
- Indian Ocean MOU and
- Riyadh MOU (covering the Arabian Gulf).

In addition to these 9 regional Port State Controls, the United States of America actively implements the Port State Control referred to as the United States Coast Guard (USCG), in line with the codes resulting from its own national laws, federal rules and international regulations.

3. TARGETING SYSTEMS USED IN PSC REGIMES

The biggest handicap that is present in almost all PSC inspection regimes is the insufficient number of inspectors in comparison with the number of vessels to be inspected. Therefore, a certain inspection rate is determined in all regional conventions. This rate varies by MOUs and is revised in time. Today, MOU target inspection rates changes between 10% and 80%.

Particularly for European and Far Eastern ports that have heavy traffic and high number of vessels calling, achieving the regional target inspection rates is quite difficult. For instance, approximately 36,000 vessels call the port of Hong Kong every year, which corresponds to an average of 100 vessels a day; and there is only 4 Port State Control Officers in charge in the area [13]. In this case, a high target inspection rate is nearly impossible to meet.

In this respect, targeting systems mainly aim to determine vessels that bear high levels of risk as per the predetermined criteria, to give priority to these vessels during the controls, to enable PSC inspections to be conducted in a more effective and relevant way, to conduct inspections by utilizing the available human resource (PSCO) more efficiently and to reduce operational time losses for vessels.

The purpose of targeting systems is to determine the vessel selection criteria in inspections carried out by PSC authorities. The factors taken into consideration in vessel selection are mainly same with each other, however there is no clarity concerning the weight of these factors [14]. Today, the information used in the targeting systems of the Paris MOU, Tokyo MOU and the USCG inspection regimes are basically defined as "target factors" and can be evaluated in two categories as "static factors" and "historical factors". Static (or general) factors consist of information that do not change throughout the life of the vessel, such as its type, design and year of built. Also the vessel's registry, manager and the class society to which it belongs may be included in this group. Historical factors, on the other hand, are based on past inspection information such as when and where the pervious inspections of the vessel were conducted, whether any deficiencies were found and whether the vessel was detained. The above mentioned target factors are weighted differently among different MOUs. General and historical factors are evaluated together and the vessels risk group and inspection priority are determined in accordance with the obtained total factor score.

The factors used in targeting systems of regional inspection regimes in order to determine vessels' inspection priorities and to establish an effective inspection system are taken into consideration in two groups as general factors and historical factors. Although the criteria used in regional regimes coincide with each other, the contents of the factors and the weights attributed to them vary from one regime to the other.

Table 1 compares the factor contents of targeting systems. It can be seen that the most detailed and most comprehensive targeting systems are the Paris MOU and Tokyo MOU New Inspection Regimes with 14 criteria. The most significant difference that separates the Paris and Tokyo MOU New Inspection Regimes from the older regimes stands out to be the "manager's performance' criterion. On the other hand, it is observed that according to the USCG risk matrix, the weights of risk scores mostly focus on the vessel's flag, manager's performance, class performance and detention reports.

Table 1. Comparison of the target factors used in PSC regimes

Risk Criteria	Criteria	USCG	Paris MOU (Old)	Paris MOU (NIR)	Tokyo MOU (Old)	Tokyo MOU (NIR)
Manager of Ship	Owner/Manager/Charterer Performance (detention rate)	+	-	+	-	+
Flag of Ship	Performance of Flag (detention rate)	+	+	+	+	+
	Approval of Flag for International Conventions	-	+	+	-	+
Class of Ship	Class Performance (detention rate)	+	+	+	-	+
	Class of ship is IACS member or not	-	+	+	+	+
Historical Data	Number of Detention	+	+	+	+	+
	Number of Deficiencies	-	+	+	+	+
	Number of not closed Deficiencies	-	+	-	+	-
	Happened Accidents	+	-	-	-	-
	Other Operational Controls	+	-	-	-	-
	Duration from latest İnspection	+	+	+	+	+
Ship Type and Age	Type of Ship and Age	+	+	-	+	-
	Ship Type	-	-	+	-	+
	Age of Ship	-	+	+	+	+

4. QUESTIONNAIRE CONCERNING THE ANALYSIS OF THE TARGETING SYSTEMS

4.1 Questionnaire Information

The prepared questionnaire aims to measure the necessity of the targeting systems employed in PSC inspection regimes, the elements that need to be included in targeting systems, and the effectiveness and efficiency of PSC inspections. During the preparation of questionnaire items the factors used in present targeting systems were taken as basis, and it has been questioned whether additional factors intended to improve the effectiveness of these systems can be introduced.

For the form of questionnaire 5 point Likert scale, which is a common questionnaire type used to determine attitudes and tendencies, was used. The questionnaire was filled out by inspectors working in different PSC regimes. Within the scope of the questionnaire, the inspectors were asked to give the answers that they think are the most suitable to their own personal opinions and experiences. The questionnaire consists of two sections. The first of these includes 6 items that define the demographic nature and professional characteristics of the participants. The second section, on the other hand, consists of 17 items that questions the participants' opinions and attitudes concerning the targeting systems used in PSC inspections. Finally, the 18th item is an open ended question directed to the participants in order to determine the most important parameter in the determination of risk factor.

4.2 Data Collection and Used Software

The questionnaire was applied on a total of 60 participants within a period of two weeks between in February and March 2013. The participants that filled out the questionnaire consist of experts working in different PSC regimes. The participants work in the Mediterranean, Black Sea, Paris and Tokyo regional PSC regimes. The first section that inquires the demographic nature and professional characteristics of the participants and the answers they have given were turned into numeric data and loaded into the SPSS 19 software. Test such as factor analysis, examination of correlation tables, frequency statistics of the answers, one-way variance analysis were performed and the reliability coefficient of the questionnaire was calculated.

4.3 Questionnaire Items

Table 2 presents the items included in the questionnaire. The items of the questionnaire can be examined under three groups. The first 3 items are related with the necessity and the effectiveness of targeting systems. While the items from 4 to 14 are related with the criteria presently being used or should have been used in target factor scoring and risk profile calculation, the items 15, 16 and 17 intend to measure the effectiveness of PSC inspections. The 18th item is a question directed to the participants in order to determine the element the participants give prominence to as the target factor in risk profile calculation.

Table 2. Questionnaire Items Concerning PSC Vessel Targeting Systems

	QUESTIONNAIRE ITEMS CONCERNING PSC VESSEL TARGETING SYSTEMS	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	PSC audit regimes should have regional target inspection rates.	□	□	□	□	□
2	It is possible to achieve the target inspection rate with the number of PSC officers in charge in your region	□	□	□	□	□
3	Availability of a "targeting system" in the selection of vessels to be inspected within the scope of PSC inspections ensures an effective inspection mechanism.	□	□	□	□	□
4	Before the inspection, the records and results of previous inspections carried out on the same vessel by the same PSC regime affect the impression of the vessel.	□	□	□	□	□
5	The records and results of previous inspections carried out on a vessel by any other MOU affect the impression of the vessel selected to be inspected.	□	□	□	□	□
6	Vessel type (tanker, dry cargo, bulk cargo, Ro-Ro, etc.) is effective in the determination of its risk factor.	□	□	□	□	□
7	Vessel's tonnage is effective in the determination of the risk factor.	□	□	□	□	□
8	Vessel's age is effective in the determination of the risk factor.	□	□	□	□	□
9	Vessel's class society (IACS member, non-IACS member, unclassed), affects the determination of its risk factor.	□	□	□	□	□
10	The performance of the vessel's manager is effective in the determination of the vessel's risk factor (according to the inspection results of the vessels managed by the same manager).	□	□	□	□	□
11	The presence of an accident history (fire, collision, grounding, severe marine pollution) of a vessel effects the determination of the vessel's risk factor.	□	□	□	□	□
12	The inclusion of the vessel's flag in the "black list or target flag list" of the MOU you serve under is effective in the determination of the vessel's risk factor.	□	□	□	□	□
13	The inclusion of the vessel's flag in the "black list or target flag list" of any MOU other than that you serve under is effective in the determination of the vessel's risk factor.	□	□	□	□	□
14	Vessels sailing under flags of convenience relatively bear a higher level of risk.	□	□	□	□	□
15	I believe -particularly vessels of high standards- lose time and personnel work force with the conducted PSC inspections.	□	□	□	□	□
16	Substandard vessels detained as a consequence of PSC inspection improve and maintain their standard after the follow-up (the 2nd) inspection.	□	□	□	□	□
17	A vessel inspected frequently as per the criteria determined by the MOU under which you serve, would relatively improve her safety standard due to frequent inspections.	□	□	□	□	□
18	What do you think is the most effective parameter in the determination of the risk factor of a vessel?	□	□	□	□	□

5. QUESTIONNAIRE RESULTS

The demographic information and professional characteristics of the 60 participants are as follows:

The average of age of the participants was calculated to be 37,5 and it was determined that 80% of the participants (48 people) are younger than 40. The average professional PSC experience of the participants was calculated to be 6,3 years, and it was determined that while 45% of the participants had less than 5 years of experience, 36,6% had an experience between 5 to 9 years. Regarding the PSC regime under which the participants serve, it was determined that most of the participants conduct inspections as per the Mediterranean MOU (60%), which are followed by those working under the Black Sea MOU with a rate of 20%. It is also understood that 83,3% of the participants had previous experience at the sea.

5.1 Reliability Analysis of the Questionnaire

The reliability of the 17-item questionnaire was determined to be Cronbach's Alpha = 0.796 in the SPSS 19 software, which is a statistically acceptable value. Furthermore, the items that negatively affect the reliability of the questionnaire were determined and the reliability coefficient the questionnaire would have if those items were to be removed was calculated. According to the obtained reliability results, it was determined that the 2nd, the 7th and the 15th items had negative contribution to the reliability of the questionnaire.

Factor analysis, which is mostly used in cases where no categorization is made before the implementation of the questionnaire, gives an idea concerning the level at which the information of the participants measure the subject matter of the questionnaire.

According to the table obtained by means of SPSS 19, it was determined that the 5 factors used in the questionnaire (age, years of professional experience, the MOU under which the participants serve, sea experience and branch) measure the subject matter of the questionnaire at a rate of 65%.

From the table obtained by subjecting the factors containing the information of the participants to correlation, it was natural to see that participants' age and professional experience correlated at the rate of 0.819 while their experience at sea and branches correlated at the rate of 0.741. What matters at this point is to see how the factors and the items (expressions) are correlated. According to the correlation table obtained by means of SPSS 19 software, it was determined that professional experience correlated with the 15th item (I believe - particularly vessels of high standards- lose time and personnel work force with the conducted PSC inspections) at a rate of 0.433, age correlated once again with the 15th item at a rate of 0.360 and the regime under which the participants serve correlated with the 2nd item (It is possible to achieve the target inspection rate with the number of PSC officers in charge in your region) at a rate of 0.333.

At this stage the level of significance of the professional experience of the participants on the items of the questionnaire. The items on which the parameter of experience plays the most significant role are the 2nd item (It is possible to achieve the target inspection rate with the number of PSC officers in charge in your region) and the 11th item (A previous accident history of the vessel (such as fire on board, collision, grounding, causing severe sea pollution, etc.) is effective in the determination of the related risk factor).

5.2 Analysis of the Answers Given to the Open Ended Question

The answers given to the open ended question "What do you think is the most effective parameter in the determination of the risk factor of a vessel?" presented in the 18th item of the questionnaire, are presented in Table 3 according the number of times they were mentioned.

This question aims to reveal the criterion the participants consider to be the most prominent and the most effective among the selection criteria for PSC inspection. The answer that was determined to be the most prominent is "the vessel's age".

The question was answered by 50 participants. The answering rate of the question is 83%. While 16 participants answered the question in the most common way, by writing down "vessel's age", 12 participants answered "manager's performance", 8 participants answered "pervious inspections", 7 participants answered "the vessel's flag" and 4 participants answered "its class". Despite the fact that 'vessel type' had been an essential part of targeting systems, only 3 participants considered it to be the most important criterion. These answers may be interpreted to indicate that the factors included in the present system are up to point. A matter that calls for the attention is the criterion of "personnel quality" was mentioned by 7 participants, who listed it mostly as the second or the third answer they can think of.

Table 3. Statistics of the answers given to the open ended question

Which Factor Determines Risk (First Answer)		
Parameter	***f***	**%**
Age	16	27%
Management Performance	12	20%
Previous Inspections	8	13%
Flag	7	12%
Class of Ship	4	7%
Ship Type	3	5%
Number of Detentions	3	5%
Personel quality	1	1%
Empty	6	10%
What Affects the Risk Factor (frequency)		
Parameter	***f***	**%**
Age	24	23%
Management Performance	18	17,50%
Previous Inspections	14	14%
Flag	14	14%
Class of Ship	12	11,50%
Ship Type	7	7%
Number of Detentions	4	4%
Personnel Quality	7	7%
Not Closed Deficiencies	2	2%

6. CONCLUSIONS

The implemented questionnaire and the conducted analysis once again set forth that the PSC inspectors' term of professional experience is crucial and significant in terms of viewing the system from an expert's perspective. 11 of the participants who filled out the questionnaire had 10 years and longer PSC experience. Examining the answers given by the experienced participants shows that:

- The opinion that the present systems are inadequate to conduct inspections at the targeted rate prevails with a rate of 63% from the answers given to the 2nd item "It is possible to achieve the target inspection rate with the number of PSC officers in charge in your region".
- In the answers given to the 7th item "Vessel's tonnage is effective in the determination of the risk factor", the opinion that using vessel's tonnage in the calculation of risk factor would not have a significant effect prevails with a rate of 63%.
- The opinions that agrees with the expression presented in the 14th item "Vessels sailing under flags of convenience relatively bear a higher level of risk" and that indicates that vessels using flags of convenience are more risky and therefore should be recognized as a target factor prevail with a rate of 63%.

The prominent opinions as per regional inspection regimes are as follows:

- Most of the participants that serve under the Mediterranean MOU consider vessels sailing under convenient flags to bear a higher level of risk (75%) and that vessel tonnage cannot be evaluated as a risk factor (67%). They believe that the most significant elements that affect risk factor are the performance of the manager, vessel's age and flag.
- Most of the participants that serve under the Tokyo MOU and the Paris MOU (87% of those from the Tokyo MOU and 75% of those from the Paris MOU) consider that inspections made on vessels of good standards may occasionally cause losses of time and workforce.
- Most of the participants serving under the Black Sea MOU believe that vessels sailing under convenient flags bear more risk (83%) and that the 2nd inspections carried out would not improve the standard of vessels (75%).

It is understood from the evaluation of the answers given to the questionnaire that it is not likely to achieve "targeted inspection rates" implemented almost in all regional regimes with the present number of inspectors. 23 of the participants (38%) indicated that they disagree with this point while 9 participants stated that they are undecided concerning the matter.

In this case, administrations and regional inspection regimes should review their target inspection rates to make them achievable with the present number of inspectors they have, or should adopt the approach of determining the vessels to be inspected and the frequencies of inspection as per the risk profile of every ship as implemented in the Paris MOU and Tokyo MOU new inspection regimes, instead of the usual target inspection rates and inspections made in every 6 months, and that vessels that are in good conditions and managed by companies known for their proper safety culture should be inspected less frequently in order to use the limited human resource and time at the most optimum way, thus improving the effectiveness of the inspections.

Another attention-grabbing matter is the hesitancy the group of participants exhibited on whether the tonnage of a vessel should be considered as a risk factor in targeting systems. While 24 participants disagreed and 17 participants agreed with the expression that questions this matter, 19 answered as undecided. Therefore, this matter should be addressed and discussed in the technical committee meetings of regional inspection regimes and PSC exchange programs; because tonnage is not an indicator of the safety standard of a vessel. In other words, safety standards of larger vessels are not expected to be lower. That being said, it is considered particularly in accident investigations and analyses that the magnitude of the consequences of accidents caused by vessels with high tonnage are mostly more severe, that risk assessment is carried out also on such vessels, that even if occasionally tonnage is accepted as a risk indicator and therefore it can be an element of also targeting systems that operate on a risk-based logic.

The fact that 43 of the answers (72%) given to the item that questions the matter whether sailing under a flag of convenience would be accepted as a risk indicator in targeting systems, indicated the participants' agreement is not worthy.

In addition, 56% of the participants indicated that they agree that an accident history the vessel has would be effective in the determination of her risk factor, while 25% of the participants remained undecided concerning this.

It is considered that a previous accident a vessel had may give some clues on the safety level of the vessel and that it can be evaluated as a historical factor. However, in the targeting systems -except for the one used by the USCG- information on the past accidents of the vessels are not taken into consideration as a target factor. Including vessels' accident histories of the last 1 or 2 years to the targeting systems or risk profile calculations of the Paris, Tokyo and Black Sea MOUs as a risk indicator or factor score would be useful.

The fact that the most common answers given to the open ended question "What do you think is the most effective parameter in the determination of the risk factor of a vessel?" presented in the 18th item were "vessel's age, manager's performance and the results of the previous inspections" confirms that the criteria used by the present targeting systems are proper and to the purpose. However, the answer "vessel's personnel quality" that can be considered as a marginal answer, points out that this dynamic factor may also be included to the targeting systems in the future.

The inspection regimes that currently utilize targeting systems, initially determined the inspection priorities of vessels on the basis of specific information and denouncements. Developing technology, increasing number of vessels, growing fleets, modernization of vessels and port facilities and the consequent shortening of operation durations and vessels becoming the critical element of the logistics system led to new developments and pursuits concerning the effectiveness of Port State Controls. In 2011, Paris MOU changed its targeting system and started to use the new inspection regime. This was later followed by the Tokyo MOU in 2014, which will probably be followed by the Black Sea MOU in the coming period. The point of importance here is to focus on "low standard" vessels and to avoid inspecting vessels with good standards at a rate more than necessary while selecting the vessels to be inspected and determining the frequency of inspections; thus establishing an effective inspection method.

Indeed, with the new inspection regime adopted by the Paris MOU in 2011, the number of inspected vessels decreased approximately by 25% in comparison with the previous years. Nevertheless, with the prohibition of poor performing vessels to call the ports, it is a fact that the activities of substandard vessels were limited at a significant extent.

Due to the fact that the targeting systems of every MOU are different, regional regimes do not acknowledge the inspections made out of their respective regions and the results of such inspections as valid indicators. A vessel that is assessed to bear a "high level of risk" according to the targeting system of a regional regime may be categorized to have "standard risk" in another regional regime. However, IMO's recent recommendatory decisions concerning PSC harmonization and the cooperation started among regional regimes signal that a coordination at least concerning the vessel inspection criteria and the determination of vessel risk profile will be established.

It is understood from the evaluation of the questionnaire that the factors in presently used targeting systems are generally consistent and capable of measuring risk levels in terms of PSC. On the other hand, in the light of the answers given by the participants, it is considered that sailing under convenient flags, pervious accident records of vessels, results of the inspections carried out by other regional regimes, and even the competency and performance of the vessels' personnel should be evaluated as risk factors and included in the targeting systems. These factors signal that targeting systems may undergo new revisions in the future.

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EXPERIMENTAL MEASUREMENTS AT UNSTEADY CONDITIONS FOR DIESEL SUPERCHARGED ENGINE AND TIME RESPONSE OF SUPERCHARGER UNITS

Associate Professor Salvadore Mugurel BURCIU

”Dunarea de Jos” University of Galati, Romania

ABSTRACT

The paper presents experimental results for the most important parameters of Diesel supercharged MB836Db engine at unsteady working conditions which are specified. The results are obtained based on measurements in the department of environmental engineering systems and thermal systems. The author point out some conclusions regarding to the influence of supercharger units time response on the engines performances in case of unsteady working conditions.

Keywords: *unsteady working conditions; Time response of free rotation supercharger units; pressure pulsations of supercharging group; Diesel supercharged MB836Db engine.*

1. INTRODUCTION

The paper presents graphics results of experimental measurements for the significant parameters of Diesel supercharged MB836Db, in case of unsteady working conditions; the conclusions about to the influence of supercharger units time response on Diesel engine performances are also presented.

2. TIME RESPONSE OF FREE ROTATION SUPERCHARGER UNITS. EXPERIMENTAL MEASUREMENTS.

The reason of readuction of the effective parameters of supercharged engines which work at unsteady conditions, given the situation of steady conditions is assigned to the transfer of energy between engine and supercharger with free rotation.

In conditions of acceleration (fast increase of revolution and/or load) only one part of energy exhaust gasses is transformed in mechanical work for compressor; the rest of theenergy is used for the acceleration of different parts in revolution and win the inertia of supercharger with free rotation. That is why the supercharger pressure in case of unsteady conditions, at any moment is considerable decreased than the supercharger pressure in steady working conditions, at the same instantaneous rotation and load. Because the debit of air is decreased for the moment of change, the working conditions and the injection system respond immediately, the burn process will be affected with apparition as black smoke and the engine’s torque and power will be decreased. Using an adequate projection of supercharged Diesel engine and supercharger units and adjusting the engine with supercharger units using also experimental tests, we try to decrease the time response of compressor in case of unsteady working conditions, thus making a connection between the working of supercharged diesel engine for unsteady working conditions with the natural aspirate engine, certainly with better performances.

In case of car engines, which work with frequent changes of speed and load, it is necessary a fast time response for supercharger units; it is recommended to use short exhaust and inlet manifolds for using the impulse of pressure.

In case of car engines, effective pressure (p_e), pressure for supercharge (p_k) and scavenging coefficient are relatively reduced, the units time response is satisfactory, and a real problem is the critical burn characteristic for unsteady working.

Figure 1, [2], [3] presents the time respons of car engine in case of an increase of acceleration, without the change of load . In this case the governer of revolution understands rapidly the increase of revolution and decreases the debit of fuel after 1 second, which causes a normal burn with an increase of supercharge pressure and normal air coefficient; black smoke in exhaust gasses is existent for only 2 seconds.

Figure 2, [4] presents the time response of a normal car engine supercharged and also the time response of the same car engine but equiped with a control system for the injection system, both on the same load. Engine equiped with the control system for the injection system which is correlated with the supercharger, on the basis of supercharge pressure, ensure for unsteady working conditions considerable decrease of the fuel consumption and black smoke in exhaust gasses, but the time response of this engine for fast increase of load is greatest than for normal car engine supercharged.

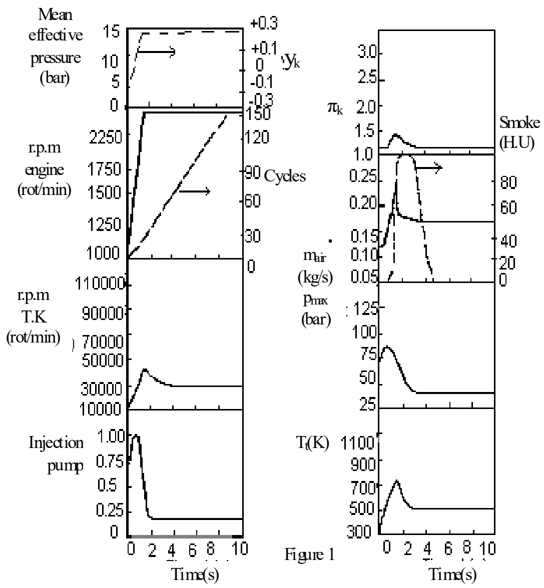

Figure 1

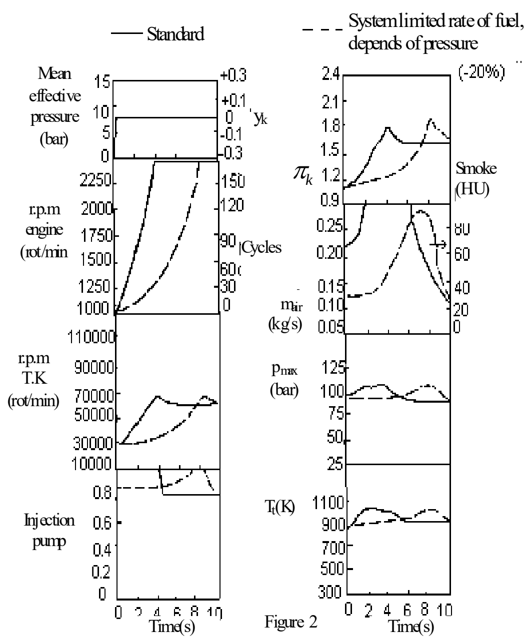

Figure 2

3. EXPERIMENTAL MEASUREMENTS OF THE AUTHOR ON THE TIME RESPONSE OF THE TURBOCHARGER

The author used for experimental determinations a naval engine or railway engine Diesel supercharged MB836Db. The engine is shown in figure 3 and 4 and is in the laboratory of the internal combustion engines of the department of environmental engineering systems and thermal systems.

Parameters of diesel supercharged MB836Db (figure 3 and 4) at MCR are:

Power 425 HP/ 1300 rpm; effective specific fuel consumption 175±5% g/HPh. Maximum permitted engine speed at full load, non-continous mode, is 1500 rpm.

Figure 3 Diesel engine MB836Db

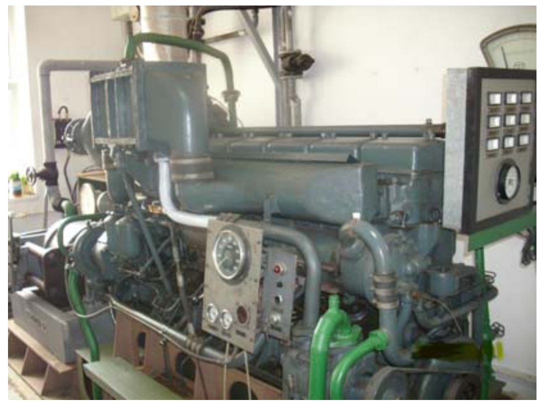

Figure 4 Diesel engine MB836Db

Diesel engine supercharged MB836Db is a four stroke engine with six cylinders, bore=175mm, stroke=205mm, compression ratio 1:16, ignition order 1-5-3-6-2-4. The engine is supercharge with a VTR200R turbocharger with free rotation, with the following characteristics: pressure range 1.4-2.5 bar, air flow 0.3 - - 1.2 m^3/s, speed range 16000—34000 rpm, gas temperature at the turbine entry, with a maximum allowable 650ºC.

Experimental determinations were performed using a test equipment which contains PLC module CBM 500 (Figure 5- Software interface of PLC module CBM500).

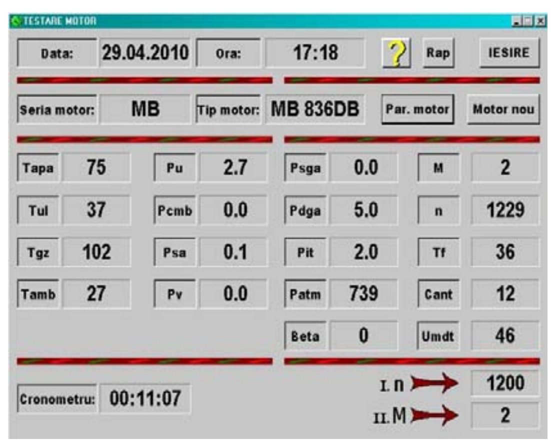

Figure 5 – Interface of PLC - CBM500

This electronic equipment contains:
-17 sensors to measure parameters on engine.
-PLC module connecting cords provided with 17 transducers arranged on equipment test.
- Display Device, which enables simultaneous viewing of 4 parameters.
- Computer program that allows acquisition measured values for the transmission to PC and graphics processing their.

Measured and displayed simultaneously: speed, torque, force at the hydraulic brake, coolant temperature, oil temperature, exhaust gas temperature, oil pressure, boost pressure (pressure supplied by the compressor), the air flow through the compressor, the total pressure of exhaust gas entering the turbocharger, gas flow through the turbine, turbocharger speed, injection advance angle, fuel consumption per hour.

Calculate values for the following parameters: effective power, effective specific fuel consumption, engine load, the power of turbocharger.

Create and lists three types of reports containing measured values, their average values, and the values for maximum load conditions. Show in graphical form the time variation of selected parameters.

The values measured and calculated by the equipment which contains PLC module CBM 500, on the diesel supercharged MB836Db engine, for steady working conditions, are shown in Table 1, 2, 3.

Table 1:The values measured and determined, steady working conditions

n_{engine} [rpm]	Load [%]	Brake force F_f [kgf]	P_e [HP]	c_h [kg/h]
700	40	112	78.4	12.86
700	60	168	117.6	18
700	80	224	156.8	24.8
700	100	280	196	31.3
800	40	118	94.4	16.36
800	60	177	141.6	22.5
800	80	236	188.8	28.8
800	100	295	236	37.9
900	40	126.4	113.8	18
900	60	189.6	170.6	25.7
900	80	252.8	227.5	33.96
900	100	316	284.4	43.9
1000	40	130	130	20.9
1000	60	195	195	30
1000	80	260	260	40.9
1000	100	325	325	55.38
1100	40	132	145.2	24
1100	60	198	217.8	34.6
1100	80	264	290.4	45
1100	100	330	363	60
1200	40	131.6	157.8	26.67
1200	60	197.4	236.7	38.3
1200	80	263.2	315.6	50
1200	100	329	394.5	66.66
1300	40	130.8	170	29.51
1300	60	196	255	43.9
1300	80	261.5	340	55.38
1300	100	327	425	75

Table 2:The values measured and determined, steady working conditions

n_{engine} [rpm]	Load [%]	M_e [daNm]	c_e [g/kWh]	p_k [bar]
700	40	78.58	223.3	1.023578
700	60	117.92	208.2	1.043578
700	80	157.2	215.4	1.163576
700	100	196.5	217.3	1.298578
800	40	82.84	235.73	1.033608
800	60	124.3	216.14	1.043578
800	80	165.64	207.5	1.168578
800	100	207.05	218.46	1.340608
900	40	88.7	215.2	1.063608
900	60	133.05	205.05	1.148578
900	80	177.4	203.1	1.23361
900	100	221.75	210.05	1.42861
1000	40	91.2	219.05	1.15358
1000	60	136.87	209.3	1.25861
1000	80	182.5	214.07	1.325608
1000	100	228.1	231.8	1.47861
1100	40	92.6	224.88	1.16858
1100	60	139	216.2	1.29861
1100	80	185.3	210.8	1.34061
1100	100	231.6	224.88	1.513608
1200	40	92.3	229.9	1.20858
1200	60	138.5	220.1	1.32561
1200	80	184.6	215.5	1.43281
1200	100	230.7	229.88	1.6136
1300	40	91.8	236.06	1.32558
1300	60	137.68	234.2	1.45861
1300	80	183.64	221.5	1.56858
1300	100	229.46	240.1	1.7836

Table 3:The values measured and determined, steady working conditions

n_{engine} [rpm]	Load [%]	m_k [kg/s]	m_g [kg/s]	n_{KT} [rpm]
700	40	0.1994	0.2388	9165.5
700	60	0.202	0.2613	9866
700	80	0.217	0.305	10696
700	100	0.239	0.348	11310.7
800	40	0.231	0.296	11276
800	60	0.237	0.31	11710.8
800	80	0.248	0.34	11877.3
800	100	0.276	0.378	12007
900	40	0.263	0.33	12382.7
900	60	0.278	0.352	12504.2
900	80	0.294	0.389	13081
900	100	0.329	0.436	13258
1000	40	0.31	0.38	13519.6
1000	60	0.333	0.408	13621.2
1000	80	0.344	0.448	14375
1000	100	0.373	0.529	15679.5

1100	40	0.345	0.419	14764.7
1100	60	0.373	0.453	14795
1100	80	0.382	0.498	15842
1100	100	0.416	0.589	17208.5
1200	40	0.385	0.53	18309.6
1200	60	0.411	0.571	18431.4
1200	80	0.435	0.609	18576
1200	100	0.478	0.69	19258
1300	40	0.448	0.593	19241.2
1300	60	0.48	0.654	19834.6
1300	80	0.51	0.724	20766
1300	100	0.562	0.812	21064.5

Using the same equipment which contains PLC module CBM 500, on the diesel supercharged MB836Db engine, experimental measurements were performed for unsteady regimes of operation, in case of four cases of unsteady conditions, namely:

Case 1: fast increase of load engine, constant acceleration, speed engine for 1000-800 r.p.m;

Case 2: fast increase of load engine, constant acceleration, speed engine for 1100-700 r.p.m;

Case 3: fast increase of acceleration, constant load, speed engine for 700-1000 r.p.m;

Case 4: fast increase of acceleration, constant load, speed engine for 700-1100 r.p.m;

Figures 6 to 10, [1] present results of experimental measurements for the effective parameters of Diesel supercharged MB836Db in case of unsteady working conditions for the four cases of unsteady conditions, specified above.

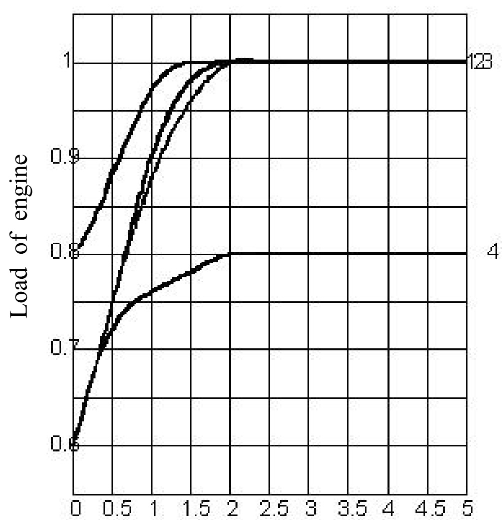

Figure 6 Time (s)

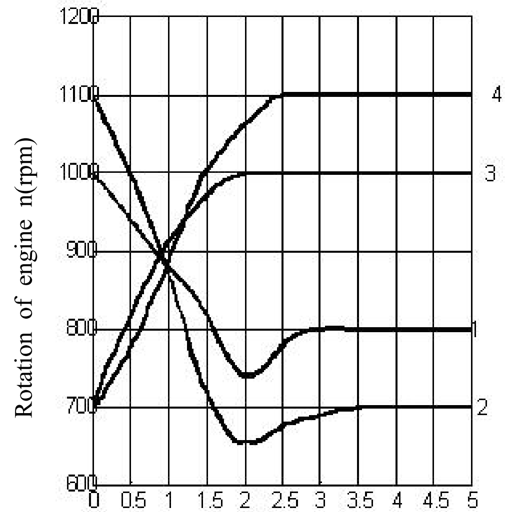

Figure 7 Time (s)

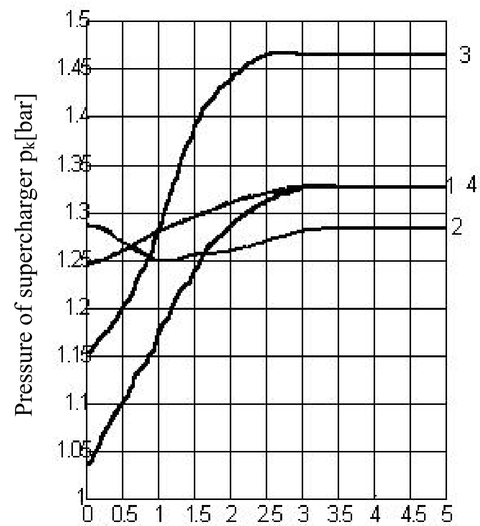

Figure 8 Time (s)

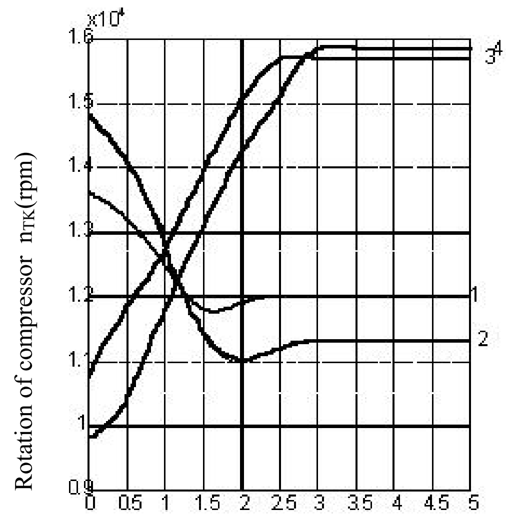

Figure 9 Time (s)

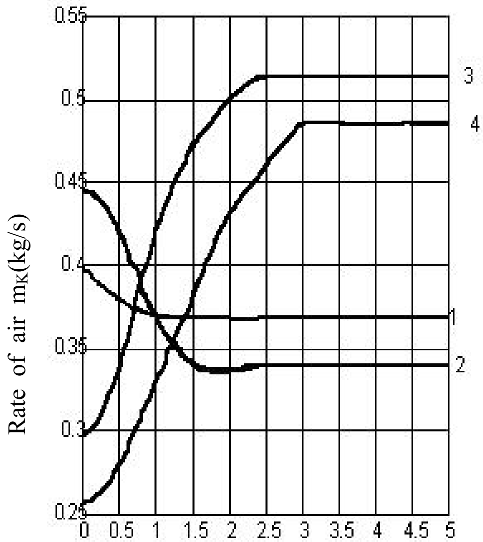

Figure 10

The number of the case is specified on the right side of the graphics. We notice that in case 3 and 4, response is faster than in cases 1 and 2.

The experimental results obtained for unsteady working conditions shows that the performances of engine and supercharger units are more reduced than the performances in steady conditions, because the compressor inertia is greater than the inertia of the injection system. Because of this issue is modified badly the quality of combustible mixture, which determines the increase of pollution and decrease of engine performances.

Disa Elektronik (Figure 11) is an equipment used for determining the non-electrical parameters (such as pressure) of thermal power plants using electrical methods.

Equipment includes the following main elements:

- oscilloscope with two spots of high precision, type 51B00 DC Universal indicator;
- amplifier stabilizer type 51 BO1 DC;
- amplifier and reactance converter, type 51B02;
- amplifier and timer, type 51BO5;
- high pressure transducer, type Pu 1, low pressure transducer, type 2a Pu;

Figure 11 Disa Elektronik Equipment

F or measuring the pulsations of pressure which is supplied by the compressor we used the Disa Elektronik equipment.

Figure 12 and Figure 13 are two examples of these pressure pulsations (pressure expressed absolute), around the mean value, pulsations recorded in real time using the equipment - Disa Elektronik, for 1 Volt sensivity on the horizontal division, 0,05 Volt sensivity on the vertical and 100μsec/division.

Measurements were performed on the load and speed regimes specified on each graph. Can see that the amplification of these pulsations and the increase of the average value of boost pressure takes place with the increasing speed and engine load.

The increasing of the average value of the boost pressure, is explained by increase the turbocharger speed, in the same time with increasing flue gas flow, which take place with increase load and speed engine.

Increasing pressure pulsations (around the mean value) of supercharging group is explained by the amplification of turbulence phenomena and the occurrence of shock waves, in the compressor and also in turbine, which take place with increasing load and speed engine.

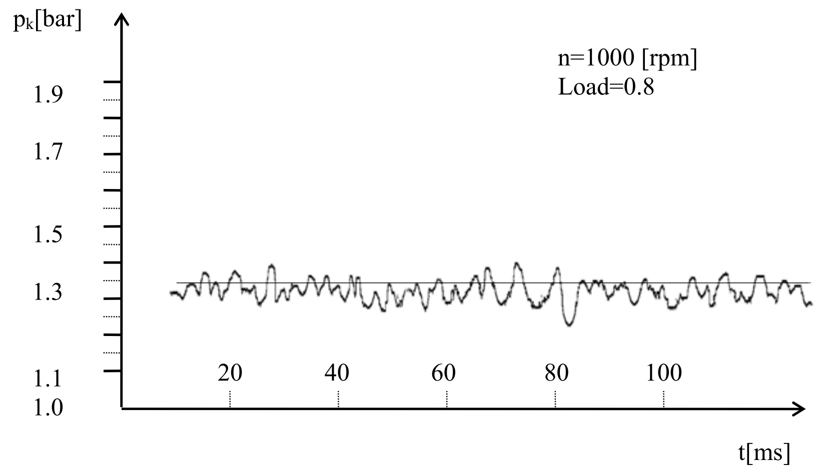

Figure 12 Pressure pulsations at 1000 rpm and 80% load

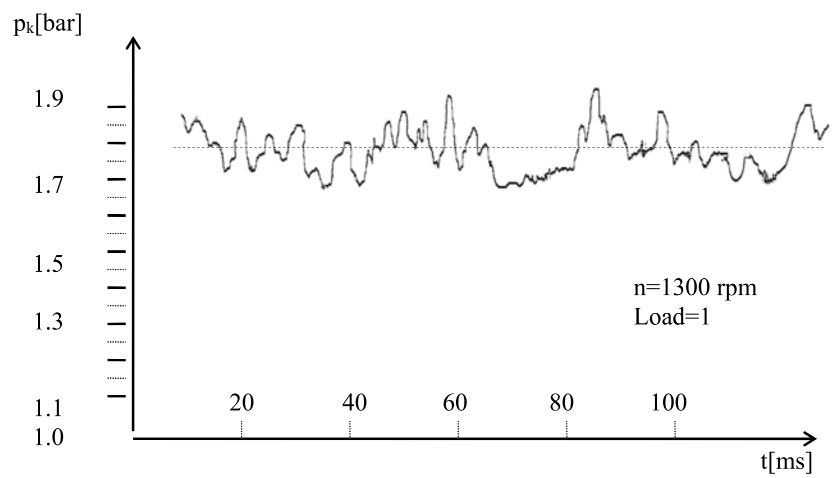

Figure 13 Pressure pulsations at 1300 rpm and 100% load

4. CONCLUSIONS

We conclude that for decreasing the time response of supercharger units with free rotation in case of unsteady working conditions it is required:

- engine with small exhaust and inlet manifold and supercharger units which uses impulse of exhaust gasses;
- supercharger units with low inertia;
- supercharger units with variable geometry;
- use a control system for the injection system.

Nomenclature

n[rpm]: rotation (speed) of engine;
M_e[daNm]:engine torque;
F_f[kgf]: hydraulic brake force to the load engine;
p_k[bar]: pressure supplied by the compressor;
m_k[kg/s]: rate of air flow through the compressor;
p_g[bar]: total pressure of exhaust gas entering the turbocharger;
m_g[kg/s]: the rate of gas flow through the turbine;
n_{TK}[rpm]: turbocharger rotation;
c_h[kg/h]: fuel consumption per hour;
c_e[g/kWh]: effective specific fuel consumption;
P_e[HP]: effective power;

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ENERGY BALANCE METHOD – A SIMPLE AND TRUSTWORTHY TECHNIQUE FOR ESTIMATING THE BEHAVIOR OF CONSERVATIVE NONLINEAR OSCILLATORS

DELEANU DUMITRU

Constanta Maritime University, Romania

ABSTRACT

Many phenomena in physics and engineering are modelled by means of conservative nonlinear oscillators. If someone is interested in a fast and reliable estimation of such an oscillator, then the He's energy balance method could be an ideal tool for solving the problem. The method provides accurate approximate analytical solutions just after a single iteration, which are uniformly valid in the whole range of parameters involved. In this article, three examples of strong nonlinear conservative oscillators are considered to describe the solution algorithm and to illustrate the simplicity and effectiveness of the energy balance method. The results are contrasted with their numerical counterparts or with other similar techniques and the conclusions concerning the merits and the drawbacks of the method are presented.

Keywords: *Conservative nonlinear oscillator, energy balance method, frequency-amplitude relationship.*

1. INTRODUCTION

Nonlinear oscillators play an important role not only in physics, but also in engineering, mathematical biology and related fields. Generally, the differential equations describing their motion are not amenable to an exact treatment and, therefore, approximate methods must be used instead. There are several new techniques appeared in the literature to get analytical approximate solutions to nonlinear problems, including homotopy perturbation method [1], variational iteration technique [2], Adomian decomposition method [3], or other approaches [4].

Between nonlinear oscillators, an important category is that of conservative oscillators for which the restoring force is independent on time and the total energy is conserved throughout the motion. Moreover, the solutions describing the oscillations are periodic and range over an entire set of initial conditions.

For the special case of single-degree-of-freedom conservative nonlinear oscillators, the Chinese mathematician He developed a simple technique, called Energy Balance Method, for finding the frequency-amplitude relationship, which represents a fundamental feature of any nonlinear oscillator [5]. In this approach, the Hamiltonian corresponding to the equation of motion is derived first, a periodic solution is assumed and, in the end, the frequency expression is readily obtained by collocation. Despite of its simplicity, the method provides excellent or, at least, reasonable accuracy for the whole range of oscillation amplitude values permitted in the analysed problem [6, 7].

In order to demonstrate the merits of the energy balance method, in the paper we will apply it to three strong nonlinear mechanical oscillators and the obtained results will be compared with their numerical counterparts or other available findings in the open literature.

2. ENERGY BALANCE METHOD. SIMPLE DESCRIPTION

Consider a single degree-of-freedom nonlinear conservative oscillator whose motion is described by the differential equation;

$$\ddot{u} + f(u) = 0,\ u(0) = A,\ \dot{u}(0) = 0\,, \qquad (1)$$

where u and t are (dimensionless) displacement and time variables, respectively. There exist a Hamiltonian

$$H = \frac{1}{2}\dot{u}^2 + F(u) = F(A)\,, \qquad (2)$$

with $K = \frac{1}{2}\dot{u}^2$ representing the *kinetic energy* and $F(u) = \int f(u)\,du$ the *potential energy* throughout the motion. Denote by R the residual;

$$R(u) = \frac{1}{2}\dot{u}^2 + F(u) - F(A)\,. \qquad (3)$$

The method assumes that the oscillation is well depicted by the trigonometric function

$$u(t) = A\cos\omega t\,, \qquad (4)$$

with ω being the unknown angular frequency of the motion. Substituting the trial function into (3), we obtain

$$R(t) = \frac{1}{2}\omega^2 A^2 \sin^2\omega t + F(A\cos\omega t) - F(A) \qquad (5)$$

Generally, the selected function (4) is just an approximation to the exact solution of problem (1). It follows that $R(t)$ is different from zero for the vast majority of ωt values. The frequency ω is determined by using collocation at $\omega t = \pi/4$, that means by imposing the condition $R(\omega t = \pi/4) = 0$. This yields

$$\omega_{apx} = \frac{2}{A}\sqrt{F(A) - F\left(A/\sqrt{2}\right)}, \tag{6}$$

and, as a consequence

$$u_{apx}(t) = A\cos\left(\frac{2}{A}\sqrt{F(A) - F\left(\frac{A}{\sqrt{2}}\right)}\, t\right). \tag{7}$$

As we will see in the next section, these simple expressions describe astonishing well the oscillatory motion. In the worst case, the relative errors do not exceed few percentages.

3. APPLICATIONS

In order to check the accuracy of the discussed technique, we consider in what follows three conservative mechanical oscillators.

3.1 A generalized Duffing-like oscillator

The first example concerns the simple oscillator

$$\ddot{u} + u^{n} = 0,\ u(0) = A,\ \dot{u}(0) = 0\,; \tag{8}$$

where n is an odd positive integer. Its Hamiltonian can be written in the form

$$H = \frac{1}{2}\dot{u}^{2} + \frac{1}{n+1}u^{n+1} = \frac{1}{n+1}A^{n+1} = \text{constant}$$

Selecting the trial function $u(t) = A\cos\omega t$, the residual becomes,

$$R(t) = \frac{1}{2}A^{2}\omega^{2}\sin^{2}\omega t + \frac{1}{n+1}A^{n+1}\left(\cos^{n+1}\omega t - 1\right).$$

According to the procedure, we get $R\cdot\left(\omega t = \frac{\pi}{4}\right) = 0$.

This condition provides us the frequency-amplitude relationship,

$$\omega_{apx}^{2} = \frac{4}{n+1}A^{n-1}\left(1 - \frac{1}{2^{\frac{n+1}{2}}}\right). \tag{9}$$

To verify the closeness between the numerical results, obtained with the MatLab package, and the approximate ones, we have carried out a number of simulations. Some of the results are displayed in Figures 1 and 2 and Tables 1 to 3. No matter if the amplitudes A are small or large, the obtained relative errors remain lower than 2.3%. For n = 1, the approximate solution coincides with the exact one. If n increases from 3 to 9 (or 11, for some A) the approximate period is smaller than its numerical counterpart and the relative errors between the two solutions diminishes. Starting with $n = 11$ the situation is reversed.

To find ω_{apx}, we collocated at $\omega t = \pi/4$ (or 45^0). This is not necessarily the best choice. The last column in Tables 1 to 3 shows us the ωt values (in degrees) which yield null relative errors between the approximate period, $T_{apx} = 2\pi/\omega_{apx}$, and its numerical equivalent, T_{num}.

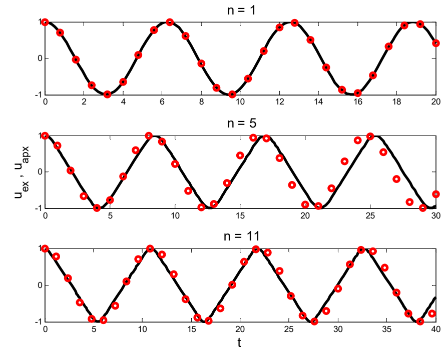

Figure 1 Comparison of analytical (small red circles) and numerical solutions (continuous black curve) for A = 1 and different exponents n

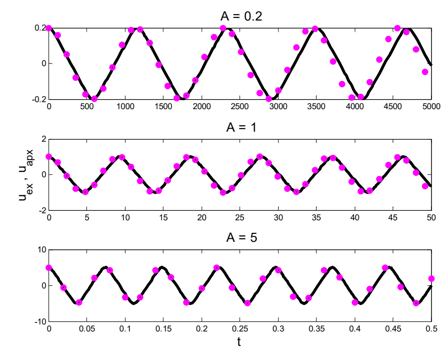

Figure 2 Comparison of analytical (magenta dots) and numerical solutions (continuous black curve) for n = 7 and different amplitudes A

Table 1. Numerical versus approximate periods and optimal choice of ωt for collocation if $A = 0.2$

n	T_{num}	T_{apx}	Relative Error (%)	Optimal ωt
1	6.28	6.28	0.00	Any
3	37.08	36.28	2.17	48.69
5	210.42	205.66	2.26	47.29
7	1163.04	1147.15	1.43	46.07
9	6385.92	6308.47	1.21	45.84
11	34156.32	34277.59	0.35	44.78

Table 2. Numerical versus approximate periods and optimal choice of ωt for collocation if $A = 1$

n	T_{num}	T_{apx}	Relative Error (%)	Optimal ωt
1	6.28	6.28	0.00	Any
3	7.41	7.26	2.02	48.56
5	8.41	8.23	2.14	47.20
7	9.31	9.18	1.39	46.12
9	10.13	10.09	0.39	45.25
11	10.89	10.97	0.73	44.54
15	12.27	12.59	2.61	43.29
25	15.18	16.02	5.53	41.87

Table 3. Numerical versus approximate periods and optimal choice of ωt for collocation if $A = 5$

n	T_{num}	T_{apx}	**Relative Error (%)**	**Optimal** ωt
1	6.28	6.28	0.00	Any
3	1.484	1.451	2.22	48.78
5	0.3364	0.3291	2.17	47.21
7	0.0744	0.0734	1.42	46.05
9	0.0162	0.01615	0.31	45.24
11	0.00348	0.00351	0.75	44.53

The problem (1) was solved approximately by means of other techniques, including the harmonic balance method [?]. In this case the result was

$$\omega_{HBM}^2 = \frac{2}{\sqrt{\pi}} A^{n-1} \frac{\Gamma\left(\frac{n+2}{2}\right)}{\Gamma\left(\frac{n+3}{2}\right)},$$

where Γ is the Bessel gamma function. Table 4 shows us the relative errors between HBM and numerical solution, for the same values of *n* and *A* used in Tables 1 to 3. It is obvious that energy balance method yields better results compared with harmonic balance method.

Table 4. Relative errors between numerical and harmonic balance methods (in percentages)

n	**A = 0.2**	**A = 1.0**	**A = 5.0**
3	2.17	2.02	2.22
5	6.53	5.47	5.50
7	8.68	8.70	8.60
9	12.35	11.55	11.73
11	14.42	14.14	13.79

3.2 A simple pendulum on a rotating rigid frame

A rigid frame is forced to rotate at the constant angular frequency Ω [8]. While the frame rotates, a simple pendulum characterized by length *r* and mass *m* oscillates (see Figure 3). Assuming that the bar ABM is weightless, the pendulum's governing equation of motion is

$$\theta'' + (1 - \Lambda\cos\theta)\sin\theta = 0, \theta(0) = A, \theta'(0) = 0 \qquad (10)$$

where $\Lambda = \frac{\Omega^2 r}{g}$ and the derivatives are taken with respect to the non-dimensional time $\bar{t} = \sqrt{\frac{g}{r}}\, t$ (see Appendix A1 for details). The Hamiltonian associated to the differential equation (10) is as follows,

$$H = \frac{1}{2}(\theta')^2 - \left(1 - \frac{\Lambda}{2}\cos\theta\right)\cos\theta = -\left(1 - \frac{\Lambda}{2}\cos A\right).$$

Considering $\theta = A\cos\omega t$ in the residual

$$R = \frac{1}{2}(\theta')^2 + (\cos\theta - \cos A)\left[\frac{\Lambda}{2}(\cos\theta + \cos A) - 1\right],$$

and collocate for $\omega t = \pi/4$, on has the following approximate frequency-amplitude relationship

$$\omega_{apx}^2 = \frac{4}{A^2}\left(\cos\frac{A}{\sqrt{2}} - \cos A\right)\left[1 - \frac{\Lambda}{2}\left(\cos A + \cos\frac{A}{\sqrt{2}}\right)\right].$$

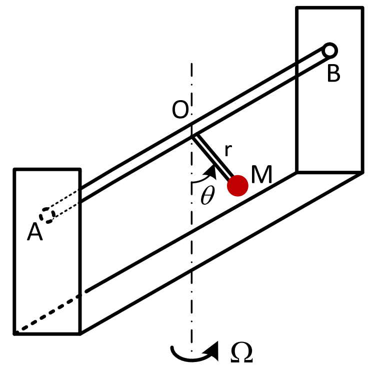

Figure 3 Simple pendulum mounted on a rotating rigid frame

The parameter Λ is proportional to frequency Ω. If $\Lambda \le 1$, one gets $\omega_{apx}^2 > 0$ for any *A*. Figures 4 and 5, respectively Tables 5 and 6, prove that $\theta_{apx} = A\cos\omega_{apx} t$ represents a trustworthy approximation for the exact solution of problem (1) even for large amplitude of oscillations (close to π). The relative errors increase with Λ, but they remain reasonably small.

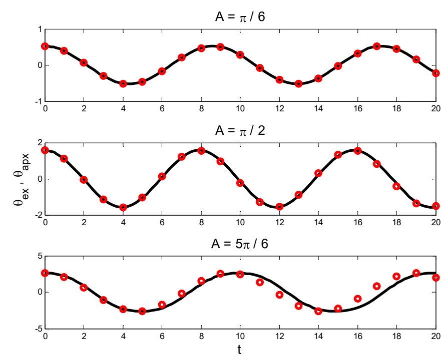

Figure 4 Comparison of analytical (red circles) and numerical solutions (continuous black curve) for $\Lambda = 0.2$ and different amplitudes *A*

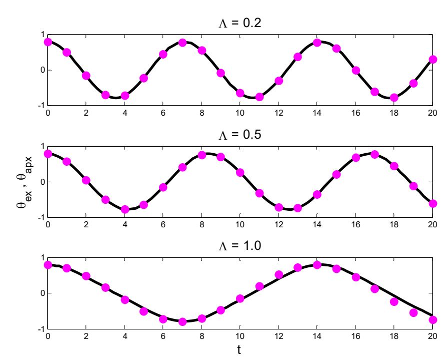

Figure 5 Comparison of analytical (magenta dots) and numerical solutions (continuous black curve) for $A = \pi/4$ and different Λ

Table 5. Numerical versus approximate periods if $\Lambda = 0.2$

A	T_{num}	T_{apx}	**Relative Error (%)**
$\pi/12$	7.033	7.021	0.18
$\pi/6$	7.059	7.060	0.02
$\pi/4$	7.111	7.101	0.15
$\pi/3$	7.202	7.202	0.00
$\pi/2$	7.576	7.589	0.16
$2\pi/3$	8.398	8.472	0.88
$5\pi/6$	10.150	10.488	3.22

Table 6. Numerical versus approximate periods if $\Lambda = 1.0$

A	T_{num}	T_{apx}	**Relative Error (%)**
$\pi/12$	39.454	40.331	2.18
$\pi/6$	20.128	20.589	2.71
$\pi/4$	13.880	14.208	2.31
$\pi/3$	10.923	11.192	2.40
$\pi/2$	8.396	8.626	2.67
$2\pi/3$	7.805	8.072	3.31
$5\pi/6$	8.547	9.074	5.81

For $\Lambda > 1$ and small A it is possible to have $\omega_{apx}^2 < 0$, because of the last factor. That means the expression for θ_{apx} provided by energy balance method ceases to represent a reliable approximation for the desired solution. A plot of ω_{apx}^2 values for $A \in [0, \pi]$ and $\Lambda \in [1, 5]$ is shown in Figure 6. The red curve signifies the border between real and imaginary values of ω_{apx}.

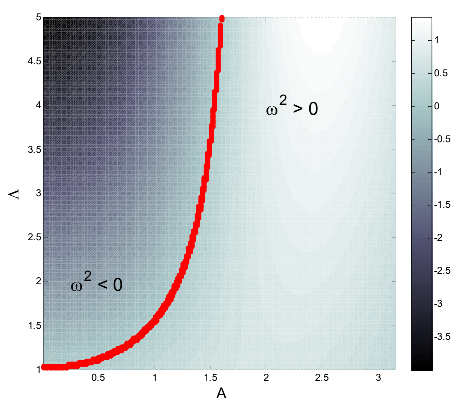

Figure 6 A plot of ω_{apx} values as a function of amplitude of oscillation, *A*, and parameter Λ

Even if ω_{apx} is a real number, the differences between T_{apx} and T_{num} are in most cases unacceptable, as illustrated in Figure 7 (relative errors exceed 10 %).

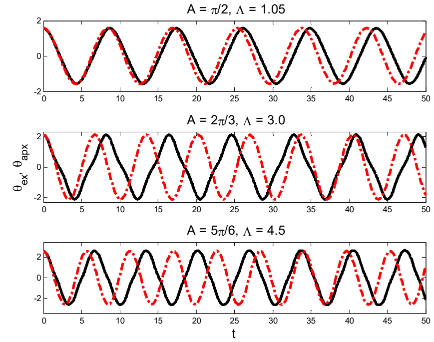

Figure 7 Comparison of analytical (discountinuous red line) and numerical solutions (continuous black curve) for some pairs (A, Λ)

3.3 A rigid rod rocking back and forth on a circular surface without slipping

Consider a homogeneous rigid bar of length *l* and mass *m* rocking back and forth on a circular surface of radius *r* (see Figure 8). Assuming no slipping effects and thinking that at rest condition the bar is in horizontal position with the centre of mass overlapped over the highest point of the semi-cylinder, the differential equation of motion is

$$\ddot{\theta} + a\left(\theta\dot{\theta}^2 + \theta^2\ddot{\theta}\right) + b\,\theta\cos\theta = 0,\ \theta(0) = A,\ \dot{\theta}(0) = 0 \quad (11)$$

where $a = \dfrac{12r^2}{l^2}$ and $b = \dfrac{12gr}{l^2}$ (see Appendix A2) [9].

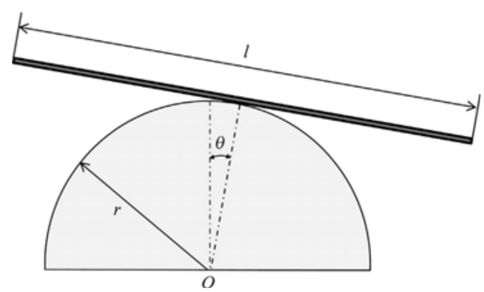

Figure 8 Rigid bar rocking back and forth on a semi – circular cylinder

The Hamiltonian for this conservative mechanical system has the form

$$H = \frac{1}{2}\dot{\theta}^2 + \frac{a}{2}\theta^2\dot{\theta}^2 + b(\cos\theta + \theta\sin\theta) = b(\cos A + A\sin A)$$

Choosing the trial function $\theta = A\cos\omega t$, replacing it in the residual and imposing the condition $R(\omega t = \frac{\pi}{4}) = 0$, we get for the approximate frequency-amplitude dependence the formula:

$$\left(\omega_{apx}^{EBM}\right)^2 = \frac{8b\left(\cos A - \cos\frac{A}{\sqrt{2}} + A\sin A - \frac{A}{\sqrt{2}}\sin\frac{A}{\sqrt{2}}\right)}{A^2\left(aA^2+2\right)}. \quad (12)$$

The same problem has been solved by Ghasemi et al [10] with Modified Homotopy Perturbation method (MHPM), and the outcome for ω_{apx} was

$$\omega_{apx}^{MHPM} = \sqrt{\frac{b\left(5A^4-72A^2+192\right)}{96\left(aA^2+2\right)}}. \quad (13)$$

To check the accuracy of the relation (12), equation (11) was integrated for various oscillation amplitudes and a = 3, b = 29.43 (or, equivalently, r = 1 and l = 2). Part of the results are reported in Table 7. There, the outcomes of MHPM are included too for the sake of comparison. As stated in [10], the results of numerical and MHPM analytical solution are almost coincidence for all investigated amplitudes A. The relative errors do not outrun 2%. Regarding energy balance method, the situation is even better. If for small amplitudes the errors are practical identical with those of MHPM, for large A the frequency – amplitude relationship (12) yields the best accuracy.

Table 7. Numerical versus analytical frequencies provided by modified homotopy and energy balance methods

A	ω_{apx}^{EBM}	ω_{apx}^{MHPM}	ω_{num}
$\pi/24$	5.3393	5.3393	5.3428
$\pi/18$	5.2747	5.2748	5.2810
$\pi/12$	5.0994	5.0993	5.1000
$\pi/6$	4.3299	4.3293	4.3633
$\pi/4$	3.4481	3.4455	3.4752
$\pi/3$	2.6205	2.6164	2.6444

4. CONCLUSIONS

The purpose of the paper was to apply the energy balance method (EBM for short) to three strongly nonlinear conservative oscillators, namely a generalized Duffing-like system, a simple pendulum on a rotating rigid frame and a rigid bar rocking back and forth on a semi – circular cylinder.

The main conclusions of the study are as follows:

a) The method has a very simple solution algorithm and acceptable accuracy of the results. The computation time for yielding an approximate analytical solution does not exceed a couple of minutes, depending on the mathematical abilities of the involved person. The relative errors with respect to the exact or numerical solution remain lower than five percentages for the vast majority of the simulations. With other words, the method is very effective and convenient for conservative nonlinear oscillators;

b) Contrasted with other well-known analytical techniques, like homotopy perturbation method (HPM) or variational iteration method (VIM), the EBM has some obvious merits and drawbacks. The most important are:

b $_1$) EBM does not require complex calculations involving optimal determination of the Lagrange multipler and computation of (sometimes) difficult integrals (this is the case of VIM) or choosing the best linear operator and trial function and solving linear differential equations (like for HPM). Instead of these, the EBM needs only to write the Hamiltonian, to assume a periodic solution and to use the collocation technique for finding the frequency-amplitude relationship.

b $_2$) EBM has some disadvantages as well. Thus, it can be applied just to the limited class of oscillators for which a Hamiltonian is available and the behaviour is characterized by simple harmonic oscillations. Additionally, the method is unable to provide higher order of approximation to the solution.

As a final remark, it will be interesting to know if the method can be generalized for nonlinear systems with more than one-degree-of-freedom. This could be a topic for further research.

5. APPENDICES

Appendix A1

The motion of mass m takes place according to the Newton's law for relative motion:

$$m\vec{a}_r = \vec{R} + \vec{F}_t + \vec{F}_C : \quad (A1)$$

where $\vec{a}_r, \vec{R}, \vec{F}_t$ and $\vec{F}_C$ signify the vectors relative acceleration, resulting force of external and connection forces (here, the weight $m\vec{g}$ and tension $\vec{S}$ in the weightless bar), transport and Coriolis forces, respectively [11, 12]. The last two are given by $\vec{F}_t = -m\vec{a}_t$ and $\vec{F}_C = -m\vec{a}_C = -2m\left(\vec{\Omega}\times\vec{v}_r\right)$ (see Figure 9).

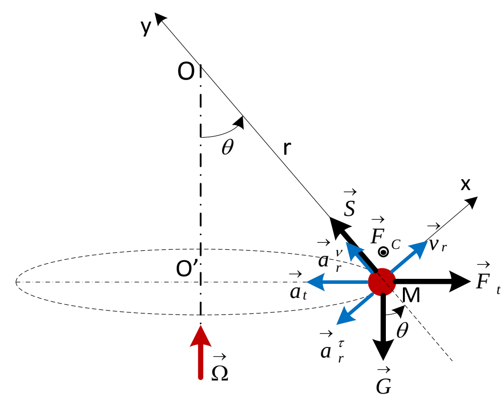

Figure 9 Distribution of forces and accelerations on the simple pendulum mounted on a rotating rigid frame

Because Ω is constant, then $\vec{a}_t$ is directed on the line MO', from M to O', and has the magnitude $a_t = MO'\cdot\Omega^2 = r\Omega^2\sin\theta$. As a consequence, $F_t = ma_t = mr\Omega^2\sin\theta$. The vectors angular velocity $\vec{\Omega}$ and relative velocity $\vec{v}_r$ belong to the plane (OO'M), so the force $\vec{F}_C$ is perpendicular onto this plane (exit from it).

By projecting the equation (A1) on the perpendicular line to the wire direction, one has

$$m a_r^\tau = m g \sin\theta - F_t \cos\theta .$$

But $a_r^\tau = r\ddot{\theta}$, so the equation of relative motion can be written in the form

$$\ddot{\theta} + \left(\frac{g}{r} - \Omega^2 \cos\theta\right)\sin\theta = 0$$

or, by using the change of time variable $\bar{t} = \sqrt{\frac{g}{r}}\, t$ and the notation $\Lambda = \frac{\Omega^2 r}{g}$,

$$\theta'' + (1 - \Lambda\cos\theta)\sin\theta = 0 \qquad \text{(A2)}$$

Appendix A2

An appropriate approach for finding the governing equation of motion for the rigid rod is given by kinetic energy-work theorem, $dK = dW$ [13]. The bar performs a plane-parallel motion, so its kinetic energy is:

$$K = \frac{1}{2} m v_C^2 + \frac{1}{2} J_C \omega_b^2 .$$

With respect to the reference frame O'xy (see Figure 10) , the center of mass coordinates are;

$$x_C = r\sin\theta - r\theta\cos\theta,\ y_C = r\theta\sin\theta - r(1-\cos\theta),$$

thus

$$v_C^2 = \dot{x}_C^2 + \dot{y}_C^2 = \left(r\theta\dot{\theta}\sin\theta\right)^2 + \left(r\theta\dot{\theta}\cos\theta\right)^2 = r^2\theta^2\dot{\theta}^2 .$$

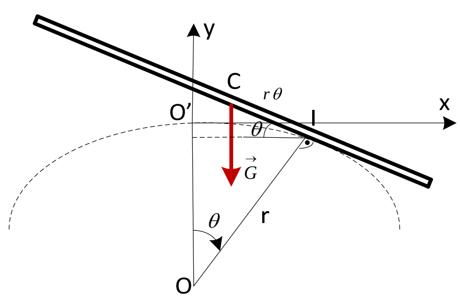

Figure 10 Geometry of rigid bar on the circular surface

For a homogeneous bar having length *l* and mass *m*, the polar moment of inertia J_C is equal with $J_C = \frac{ml^2}{12}$. Because the sliding effect is neglected, the instantaneous centre of rotation is located at I, the contact point between the bar and the circular surface, so

$$\omega = \frac{v_C}{IC} = \frac{r\theta\dot{\theta}}{r\theta} = \dot{\theta} .$$

It follows that $K = \frac{mr^2}{2}\theta^2\dot{\theta}^2 + \frac{ml^2}{24}\dot{\theta}^2$. The bar is raising its centre of mass with the distance y_C, thus the work performs by the weight force is

$$W = -m g y_C = -m g r(\theta\sin\theta + \cos\theta - 1).$$

Putting all these together, we have

$$dK = dW \Leftrightarrow \frac{mr^2}{2}\left(2\theta\dot{\theta}^3 + 2\theta^2\dot{\theta}\ddot{\theta}\right)dt + \frac{ml^2}{24}\cdot 2\dot{\theta}\ddot{\theta}\,dt =$$

$$= -m g r\left(\dot{\theta}\sin\theta + \theta\cos\theta\cdot\dot{\theta} - \sin\theta\cdot\dot{\theta}\right)dt$$

After some algebra one gets

$$\ddot{\theta} + \frac{12 r^2}{l^2}\left(\theta\dot{\theta}^2 + \theta^2\ddot{\theta}\right) + \frac{12 g r}{l^2}\theta\cos\theta = 0 \qquad \text{(A3)}$$

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ANALYTICAL DETERMINATION OF UOE PIPE RESIDUAL STRESSES BASED ON STRAINS RESULTED FROM EXPERIMENTAL STUDY

[1]DELISTOIAN DMITRI, [2]CHIRCHOR MIHAEL

[1]Constanta Maritime University, [2]Ovidius University of Constanta, Romania

ABSTRACT

From the manufacturing and continue with exploitation, residual stresses are presented in all lifetime of pipeline. Considering stresses coming from manufacturing, environment, cyclic loads and human factors, the risk of pipeline damage significantly increases. From this reason appeared a need to know the level of residual stresses that remains after manufacturing process. In present study are analytically determined residual stresses for DN 400 (16 inch) UOE double submerged arc welded pipe, fabricated from L415MB (X60) steel. The analytical model proposed allows residual stresses determination using L415MB (X60) steel stress – strain curve and strains resulted from experimental simulation.

Keywords: *strains, residual stresses, stress – strain curve, bending moment*

1. INTRODUCTION

UOE pipe manufacturing process is based on cold forming process. Cold forming is process by which metal is shaped without removing material.

Based on international abbreviation, UOE and according to [13], manufacturing process is presented by 3 principal technological steps (Fig.1), so: U – represents when plate is formed into U – shape, O – represents the moment when U shape is pressed into circular shape and final step E– represent pipe expanding operation to obtain standard size of pipe by applying radial oriented internal pressure, but always, first step is edge crimping operation that means edge preparing for weld seam execution, i.e. plate edges crimping into circular shape.

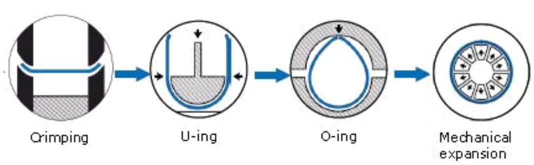

Figure 1 UOE pipe manufacturing process, by [12]

The level of residual stresses, resulted during manufacturing process, is essential for UOE pipe stress and strain state study. Special attention requires the last technological step – expanding, because produces circumferential stresses that exceeds yield point of material. From this reason, in pipe wall can occur combined stresses (residual stresses resulted from bending operations + residual stresses resulted from expanding + exploitation stresses), which can exceed ultimate strength.

X60 steel stress-strain curve, as shown in figure 1, represents principal way to residual stress determination.

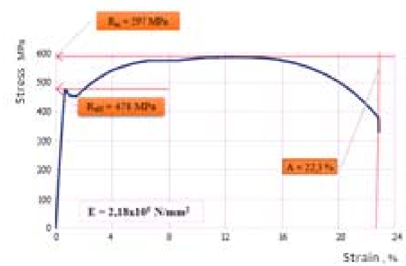

Figure 1 X60 steel stress – strain curve, by [6]

According to [1] and [2], residual stress - σ_{res} represents the differences between maximum stresses σ_{max} and return stresses - σ_{ret} :

$$\sigma_{res} = \sigma_{max} - \sigma_{ret}. \tag{1}$$

This formula is available for all technological steps. First 3 stages are based on bending and from this case are needed to know radius of curvature to calculate bending moment. Radius of curvature was calculated according to spring back proprieties of materials, so radius of curvature – ρ for edge crimping and for U shape is 175 mm, but for O shape is 195 mm [14]. Last operation - expanding is performed due to internal pressure loading and according to [14], pressure value for expanding operation is p = 17 MPa.

Hereafter, in figure 2, is presented residual stresses distribution, namely loading and relaxing processes are presented.

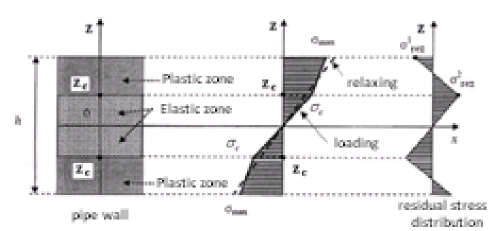

Figure 2 Residual stresses distribution, by [5]

For analytical study UOE manufacturing process is divided in the next technological steps:

1. Edge crimping;
2. Material relaxing after loading;
3. ”U” shape;
4. Material relaxing after loading;
5. ”O” shape;
6. Material relaxing after loading;
7. Expanding;
8. Material relaxing after loading;

Therefore, residual stresses are calculated after each loading and relaxing.

2. RESIDUAL STRESSES RESULTED AFTER EDGE CRIMPING

Manufacturing process is starting with plate edge crimping. Operation it was monitored by Digital 3D Image Correlation System Q-400 [15]. According to [14] and to figure 3, after edge crimping operation resulted the next maximum principal strains:

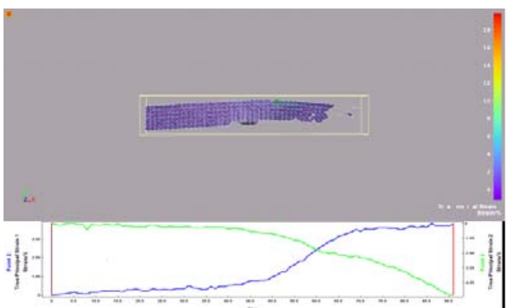

Figure 3 Edge crimping operation, by [14]

$\varepsilon_{max}^{1} = 2{,}78\%$

$\varepsilon_{max}^{2} = -2{,}89\%$

Mention is that indexes 1 and 2 represents strains resulted from principal direction 1 and 2. Result is that stresses are calculated for principal direction 1 and 2.

After edge crimping, residual stresses have the following form:

$$\sigma_{res}^{1} = \sigma_{max}^{1} - \sigma_{ret} \quad (2)$$

$$\sigma_{res}^{2} = \sigma_{max}^{2} - \sigma_{ret}$$

where:

σ_{res}^{1} – residual stress for principal direction 1, MPa;

σ_{max}^{1} – maximum stress for principal direction 1, MPa;

σ_{res}^{2} – residual stress for principal direction 2, MPa;

σ_{max}^{2} – maximum stress for principal direction 2, MPa;

σ_{ret} – return stress, MPa;

Using stress-strain curve, maximum principal direction is determined in correspondence with maximum principal strains. Result is the next:

$\sigma_{max}^{1} = 510 MPa;$

$\sigma_{max}^{2} = 495 MPa;$

After load removing, material is relaxing. According to [3], during material relaxing appears moment of returning - M_y^{ret}, which creates along with section modulus returning stresses. Bending is available for each manufacturing step, less expanding. From this reason, returning stresses have the following form [4];

$$\sigma_{ret} = \frac{M_y^{ret}}{W_y} \quad (3)$$

where:

σ_{ret} - return stress for edge crimping, MPa;

M_y^{ret} - moment of returning, N*mm;

W_y - section modulus, mm^3;

According to [5] moment of returning has the following form:

$$M_y^{ret} = \frac{1}{4}bh^2\sigma_c - \frac{1}{3}b\rho^2\frac{\sigma_c^3}{E^2} + \frac{bE_t}{4E}\left(\frac{h}{2\rho} - \frac{\sigma_c}{E}\right)\left(h^2 - h\rho\frac{\sigma_c}{E} - 2\rho^2\frac{\sigma_c^2}{E^2}\right) \quad (4)$$

where:

M_y^{ret} – moment of returning, N*mm;

h – pipe thickness, mm;

b – plate length, mm;

ρ – radius of curvature, mm;

σ_c –Yield point, mm;

E – elastic limit, MPa;

E_t – ultimate stress, MPa;

$$M_y^{ret} = \frac{1}{4}30 * 7{,}9^2 * 478 - \frac{1}{3} * 30 * 175^2\frac{478^3}{218000^2} + \frac{30 * 1081}{6}\left(\frac{7{,}9}{350} - \frac{478}{218000}\right)\left(7{,}9^2 - 7{,}9 * 175\frac{478}{218000} - 2 * 175^2\frac{478^2}{218000^2}\right) = 206856\ N * mm; \quad (5)$$

Hence the, section modulus for strip rectangular sections have the next form and value:

$$W_y = \frac{b \cdot h^2}{6} \quad (6)$$

where:

W_y - section modulus, mm^3;

b – width, mm;

h – thickness, mm;

$$W_y = \frac{b \cdot h^2}{6} = 304{,}2\ mm^3 \quad (7)$$

Returning stresses have the next form:

$$\sigma_{ret} = \frac{M_y^{ret}}{W_y} = \frac{206856\ N*mm}{304{,}2\ mm^3} = 680\ MPa \quad (8)$$

After returning stresses determination, exists possibility to calculate principal residual stresses:

$$\sigma_{res}^{1} = \sigma_{max}^{1} - \sigma_{ret} = 510 - 680 = -170\ MPa \quad (9)$$

$$\sigma_{fres}^{2} = \sigma_{fmax}^{2} - \sigma_{fret} = 493 - 680 = -187\,MPa \quad (10)$$

During edge crimping operation resulted the next residual stresses for principal direction 1 and 2:

$$\sigma_{fres}^{1} = 170\,MPa;$$
$$\sigma_{fres}^{2} = 187\,MPa;$$

3. STRESSES RESULTED AFTER „U" SHAPE OBTAINING

After edge crimping follows U press operation, where the strip is formed into U – shape. Maximum principal strains resulted after U press step, have the values presented below [14]:

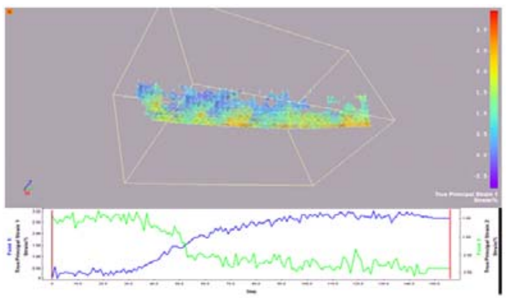

Figure 4 U shape operation, by [14]

$$\varepsilon_{Umax}^{1} = 3.2\%$$
$$\varepsilon_{Umax}^{2} = -2.6\%$$

Using stress-strain curve, maximum principal direction is determined in correspondence with maximum principal strains. Result is the next:

$$\sigma_{Umax}^{1} = 530\,MPa$$
$$\sigma_{Umax}^{2} = 500\,MPa$$

Just as in the previous step: returning stresses have the next form [4]:

$$\sigma_{Uret} = \frac{M_y^{ret}}{W_y} \quad (11)$$

where:

σ_{Uret} - return stress for edge crimping, MPa;
M_y^{ret} - moment of returning, N*mm;
W_y - section modulus, mm^3;

Bearing in mind, that strip is bended by the same radius of curvature, it means that moment of returning M_y^{ret} and returning stresses σ_{Uret}, have the same value.

Considering all the above, residual stresses resulted after U shape obtaining, have the next value:

$$\sigma_{Ures}^{1} = \sigma_{Umax}^{1} - \sigma_{Uret} = 530 - 680 = -150\,MPa$$
$$\sigma_{Ures}^{2} = \sigma_{Umax}^{2} - \sigma_{Uret} = 500 - 680 = -180\,MPa$$

During U press operation, resulted the next residual stresses:

$$\sigma_{Ures}^{1} = 150\,MPa;$$
$$\sigma_{Ures}^{2} = 180\,MPa;$$

4. RESIDUAL STRESSES RESULTED AFTER „O" SHAPE OBTAINING

After U press operation follows O press operation, where the strip is formed into O – shape. Maximum principal strains resulted after O press step, have the values presented below [14]:

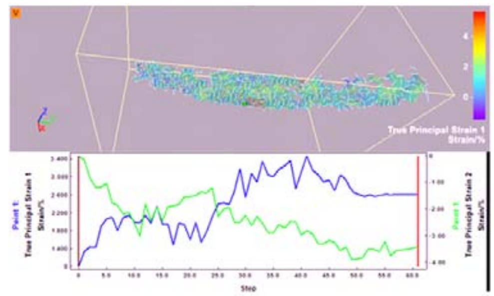

Figure 5 O shape operation, by [14]

$$\varepsilon_{Omax}^{1} = 3.7\%$$
$$\varepsilon_{Omax}^{2} = -3.4\%$$

Using stress-strain curve, maximum principal direction is determined in correspondence with maximum principal strains. Result is shown below:

$$\sigma_{Omax}^{1} = 545\,MPa$$
$$\sigma_{Omax}^{2} = 538\,MPa$$

Taking into account radius of curvature changing, for O press operation is value of ρ = 195 mm, the new value of returning moment is calculated **[5]**:

$$M_y^{ret} = \frac{1}{4} 30 * 7.8^2 * 478 - \frac{1}{3} 3 * 195^2 \frac{478^3}{218000^2} + \frac{30 * 1081}{5}\left(\frac{7.8}{350} - \frac{478}{218000}\right)\left(7.8^2 - 7.8 * 195\frac{478}{218000} - 2 * 195^2 \frac{478^2}{218000^2}\right) = 212940\,N * mm \quad (12)$$

Section modulus has the same value:

$$W_y = \frac{b s^2}{6} = 304.2\,mm^3 \quad (13)$$

Returning stresses with a new value of radius of curvature have the next form:

$$\sigma_{Oret} = \frac{M_y^{ret}}{W_y} = \frac{212940\,N * mm}{304.2\,mm^3} = 700\,MPa \quad (14)$$

Considering all the above, residual stresses resulted after O shape obtaining, have the next value:

$$\sigma_{Ores}^{1} = \sigma_{Omax}^{1} - \sigma_{Oret} = 545 - 700 = -155\,MPa \quad (15)$$

$$\sigma_{Ores}^{2} = \sigma_{Omax}^{2} - \sigma_{Oret} = 538 - 700 = -162\,MPa \quad (16)$$

During O press operation, resulted the next values of residual stresses:

$$\sigma_{Ores}^{1} = 155\,MPa;$$
$$\sigma_{Ores}^{2} = 162\,MPa;$$

5. STRESSES RESULTED AFTER PIPE EXPANDING

The last technological step is pipe expanding, which means applying of internal pressure for standard pipe sizing.

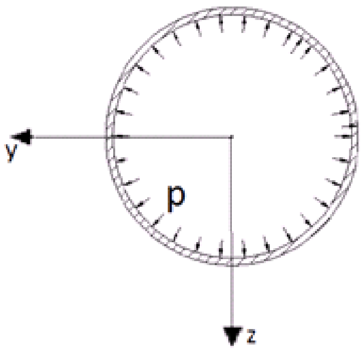

Figure 3 Pipe wall loaded by radial oriented internal pressure

Being based on API 5L standards **[7]** the pipe is to be expanded to a ratio of - greater than 0,3% and less than or equal to 1,5 % . In this case, pipe will be expanded to a ratio of 0,8%.

After expanding resulted next values of principal strains, measured on outer pipe surface [14]:

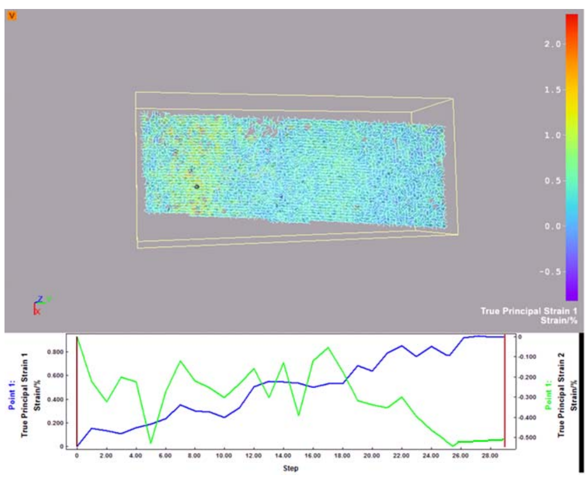

Figure 6 Expanding operation, by [14]

$\varepsilon^1_{Emax} = 0{,}98\%$
$\varepsilon^2_{Emax} = -0{,}5\%$

It should be noted that, expanded ratio it was obtained by applying pressure of 17 MPa and residual strains resulted after expanding were measured in the same areas and represents the sum of strains resulted after circular shape obtainning and expanding operation, as shown in below relations[14]:

$$\varepsilon^1_{Emax} = 3{,}3\% + 0{,}98\% = 4{,}28\% \quad (17)$$
$$\varepsilon^2_{Emax} = -2{,}6\% - 0{,}5\% = -3{,}1\% \quad (18)$$

Using stress-strain curve, maximum principal direction is determined in correspondence with maximum principal strains. Result is the next:

$\sigma^1_{Emax} = 560MPa$
$\sigma^2_{Emax} = 529MPa$

By using French engineer Gabriel Lames formula, returning stresses σ_{Eret} will be calculated by external pressure, which must applied on pipe body for internal pressure compensation [8], [9], [10]:

$$\sigma_{Eret} = -\frac{p\, r_1^2}{R_2^2 - r_1^2}\left(1 + \frac{R_2^2}{r^2}\right) \quad (19)$$

where:
p – Expanding pressure, MPa;
r_1 – inner radius, mm;
R_2 – outer radius, mm;
r – needed radius for stress calculation, mm;

According to [11] for UOE DN 400 pipe, inner radius is 195 mm and outer radius is 203 mm.

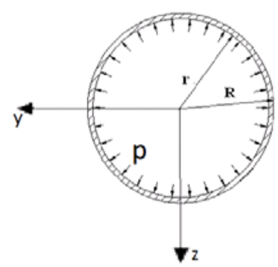

Figure 4 Inner and outer radius of expanded pipe

Next will be calculated returning stresses for outer surface.

Returning stresses for outer surface with radius $R_2 = 203\ mm$ is the next:

$$\sigma_{Eret} = -\frac{p\, r_1^2}{R_2^2 - r_1^2}\left(1 + \frac{R_2^2}{r^2}\right) \quad (20)$$

$$= -\frac{17 \cdot 195{,}2^2}{203^2 - 195{,}2^2}\left(1 + \frac{203^2}{203^2}\right) = -416MPa$$

By using, maximum principal strains, residual stresses resulted after expanding operation have the next values:

Residual stresses for outer surface:

$$\sigma^1_{Eres} = \sigma^1_{Emax} - \sigma_{Eret} = 560 - 416 = 144MPa \quad (21)$$

$$\sigma^2_{Eres} = \sigma^2_{Emax} - \sigma_{Eret} = 529 - 416 = 113MPa \quad (22)$$

Stress values of $\sigma^1_{Eres} = 144MPa$, represents maximum value of residual stress which remains on pipe surface.

6. CONCLUSIONS

Using residual strain maximum values resulted after experimental study, it was possible to perform analytical study to determine residual stresses after each technological steps.

In table 1, shown below, are presented residual stresses values after each technological step.

Table 1 Residual stresses resulted after analytical study

Stresses		ANALYTICAL STUDY [MPa]
J	σ^1_{Jres}	170
	σ^2_{Jres}	187
U	σ^1_{Ures}	150
	σ^2_{Ures}	180
O	σ^1_{Ores}	165
	σ^2_{Ores}	172
E	σ^1_{Eres}	144
	σ^2_{Eres}	118

In figure 5 is presented residual stress evolution.

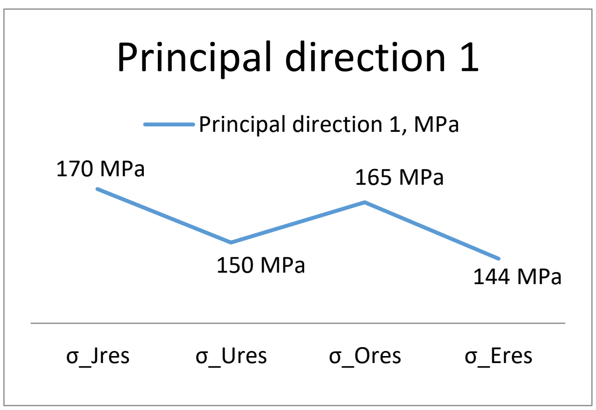

Figure 5 Residual stress evolution for principal direction 1

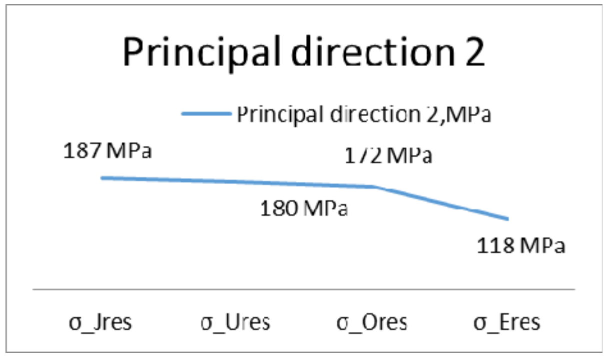

Figure 6 Residual stress evolution for principal direction 2

After UOE pipe fabrication process, resulted a surface residual stress value of 144 MPa, which represents 30% of Yield point. This demonstrates that after pipe expanding remains stress concentration areas. Being based on this study, perspective research may be a UOE method improving to reduce residual stresses level after each technological step.

This study has an evaluation character and for accurate assessment of pipe stress and strain state needs to perform numerical modeling using finite element analysis software packages.

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SHIP MANOEUVRING PERFORMANCE IN SHALLOW WATER RESTRICTION

OBREJA DAN

"Dunarea de Jos" University of Galati, Faculty of Naval Architecture, Romania

ABSTRACT

The estimation of the ships manoeuvring performance, operating in deep water or shallow water condition constitutes an important problem, which must be solved in the initial design stage. In this paper, a practical evaluation of the mentioned problem was performed for three types of ships (supply vessel, river coaster and ferryboat), based on a computer code developed in the Research Centre of the Naval Architecture Faculty of “Dunarea de Jos” University of Galati. In order to study the ship motion in horizontal plane, the mathematical model proposed by Abkowitz was used. The influence of the shallow water depth was analysed in the case of the turning circle manoeuvre and course keeping problem. Important increases of the steady turning diameter and of the stability on route parameter were identified, during the shallow water restriction.

Keywords: *supply vessel, river coaster, ferryboat, manoeuvring, shallow water.*

1. INTRODUCTION

The investigation of the ship manoeuvring performance in the initial design process constitutes an important problem.

The knowledge of the ship response to the standard manoeuvres tests in horizontal plane is essential, in order to determine the manoeuvring characteristics [1].

The manoeuvrability concept includes: controlled change of the ship route, stability on route (course keeping) and ship stopping [2].

The manoeuvring characteristics depend of the operating conditions. If the ship operates in shallow water condition, an important variation of the manoeuvring performances may be obtained, compared with deep water case.

The shallow water condition is defined by the following relation

$$H/T = 1.2 - 1.5 \tag{1}$$

where H is the water depth and T is the medium draught of the ship. However, the variation of the manoeuvring performances can be identified starting with the domain of the medium depth

$$H/T = 1.5 - 3 \tag{2}$$

In order to estimate the ship manoeuvring performances, the mathematical model proposed by Abkowitz [1] was used and the software platform PHP Manoeuvrability was developed in the Research Centre of the Naval Architecture Faculty in “Dunarea de Jos” University of Galati ([3], [4], [5]).

Using the mentioned software platform, a practical evaluation of the turning circle and course keeping characteristics in deep water and shallow water conditions was performed, for three types of ships (supply vessel, river coaster and ferryboat [6]) having the same design speed and one rudder.

The main dimensions of the ships are depicted in Tables 1-3. The rudder area is about 2% from the wetted lateral area in the case of river coaster, and about 3% from the wetted lateral area in the cases of the supply vessel and ferryboat.

Table 1. Main characteristics of the supply vessel

Ship characteristics	Value
Volumetric displacement, ∇	1910 m^3
Length of waterline, L_{WL}	54.64 m
Breadth, B	12.08 m
Medium draught, T	4.5 m
Longitudinal centre of gravity, x_G	24.36 m
Block coefficient, C_B	0.643
Rudder area, A_R	7.4 m^2
Rudder aspect ratio, λ	1.25
Design speed, U	18 Km/h

Table 2. Main characteristics of the river coaster

Ship characteristics	Value
Volumetric displacement, ∇	2099 m^3
Length of waterline, L_{WL}	61.335 m
Breadth, B	11.4 m
Medium draught, T	3.8 m
Longitudinal centre of gravity, x_G	30.665 m
Block coefficient, C_B	0.79
Rudder area, A_R	4.6 m^2
Rudder aspect ratio, λ	1.15
Design speed, U	18 Km/h

Table 3. Main characteristics of the ferryboat

Ship characteristics	Value
Volumetric displacement, ∇	2885 m^3
Length of waterline, L_{WL}	84.485 m
Breadth, B	14.365 m
Medium draught, T	4.8 m
Longitudinal centre of gravity, x_G	42.465 m
Block coefficient, C_B	0.495
Rudder area, A_R	12 m^2
Rudder aspect ratio, λ	1.333
Design speed, U	18 Km/h

2. MATHEMATICAL MODEL

A simplified linear form of the differential equations system of the ship motions in horizontal plane may be written as ([1], [2])

$$\begin{aligned} &X_e + X_u u + X_{\dot u}\dot u = m\dot u \\ &Y_e + Y_v v + Y_r r + Y_{\dot v}\dot v + Y_{\dot r}\dot r = m(\dot v + rU + \dot r x_G) \\ &N_e + N_v v + N_r r + N_{\dot v}\dot v + N_{\dot r}\dot r = I_{zz}\dot r + m x_G(\dot v + rU) \end{aligned} \tag{3}$$

where X_e, Y_e and N_e are the longitudinal force, lateral force and yaw moment, generated by the rudder deflection. Also, U is the initial ship speed, m is the displacement, I_{zz} is inertia moment of the ship around the vertical axis, u and v are the longitudinal and lateral components of the ship speed in the origin of the coordinate system and r is the angular speed around the vertical axis. With $\dot u, \dot v, \dot r$ are noted the corresponding acceleration components.

The hydrodynamic derivatives X_u, $X_{\dot u}$, Y_v, Y_r, $Y_{\dot v}$, $Y_{\dot r}$, N_v, N_r, $N_{\dot v}$, $N_{\dot r}$ were estimated in the case of deep water condition by using the relations of Clarke, Gedling and Hine [2]

$$\begin{aligned} &Y'_{\dot v} = -\pi\cdot(T/L_{WL})^2\cdot\left[1+0{,}16\cdot C_B\cdot(B/T) - 5{,}1\cdot(B/L_{WL})^2\right] \\ &Y'_v = -\pi\cdot(T/L_{WL})^2\cdot\left[1+0{,}4\cdot C_B\cdot(B/T)\right] \\ &Y'_{\dot r} = -\pi\cdot(T/L_{WL})^2\cdot\left[0{,}67\cdot(B/L_{WL}) - 0{,}0033\cdot(B/T)^2\right] \\ &Y'_r = -\pi\cdot(T/L_{WL})^2\cdot\left[-0{,}5+2{,}2\cdot(B/L_{WL}) - 0{,}08\cdot(B/T)\right] \\ &N'_{\dot v} = -\pi\cdot(T/L_{WL})^2\cdot\left[1{,}1\cdot(B/L_{WL}) - 0{,}041\cdot(B/T)\right] \\ &N'_v = -\pi\cdot(T/L_{WL})^2\cdot\left[0{,}5+2{,}4\cdot(T/L_{WL})\right] \\ &N'_{\dot r} = -\pi\cdot(T/L_{WL})^2\cdot\left[1/12+0{,}017\cdot C_B\cdot(B/T) - 0{,}33\cdot(B/L_{WL})\right] \\ &N'_r = -\pi\cdot(T/L_{WL})^2\cdot\left[0{,}25+0{,}039\cdot(B/T) - 0{,}56\cdot(B/L_{WL})\right] \\ &Y'_\delta = 3\cdot\frac{A_R}{L_{WL}^2} \\ &N'_\delta = -\frac{Y'_\delta}{2} \end{aligned} \tag{4}$$

In the case of shallow water restriction, the following adimensional hydrodynamic derivatives may be determined using the Clarke relations [2]

$$\begin{aligned} &\frac{Y'_{\dot v}}{Y'_{\dot v_\infty}} = K_0 + \frac{2}{3}\cdot K_1\cdot\frac{B}{T} + \frac{8}{15}\cdot K_2\cdot\left(\frac{B}{T}\right)^2 \\ &\frac{N'_{\dot r}}{N'_{\dot r_\infty}} = K_0 + \frac{2}{5}\cdot K_1\cdot\frac{B}{T} + \frac{24}{105}\cdot K_2\cdot\left(\frac{B}{T}\right)^2 \\ &\frac{Y'_v}{Y'_{v_\infty}} = K_0 + K_1\cdot\frac{B}{T} + K_2\cdot\left(\frac{B}{T}\right)^2 \\ &\frac{N'_v}{N'_{v_\infty}} = K_0 + \frac{2}{3}\cdot K_1\cdot\frac{B}{T} + \frac{8}{15}\cdot K_2\cdot\left(\frac{B}{T}\right)^2 \\ &\frac{Y'_r}{Y'_{r_\infty}} = K_0 + \frac{2}{3}\cdot K_1\cdot\frac{B}{T} + \frac{8}{15}\cdot K_2\cdot\left(\frac{B}{T}\right)^2 \\ &\frac{N'_r}{N'_{r_\infty}} = K_0 + \frac{1}{2}\cdot K_1\cdot\frac{B}{T} + \frac{1}{3}\cdot K_2\cdot\left(\frac{B}{T}\right)^2 \end{aligned} \tag{5}$$

where with ∞ index were noted the derivatives determined in the case of deep water.

The coefficients F and K_i (i=0, 1, 2) are given by the following relations

$$\begin{aligned} &K_0 = 1 + \frac{a_0}{F^2} + \frac{b_0}{F^3} \\ &K_1 = \frac{a_1}{F} + \frac{b_1}{F^2} + \frac{c_1}{F^3} \\ &K_2 = \frac{a_2}{F} \\ &F = \frac{h}{T} - 1 \end{aligned} \tag{6}$$

where

$$\begin{aligned} &a_0 = 0{,}00774 \\ &a_1 = -0{,}0125 \\ &a_2 = 0{,}0431 \\ &b_0 = -0{,}0151 \\ &b_1 = 0{,}1674 \\ &c_1 = -0{,}0199 \end{aligned} \tag{7}$$

By solving the system (3), the steady turning diameter *STD* and the drift angle β may be obtained using the following relations

$$STD = \frac{2\cdot U\cdot C}{\delta\cdot(N_v\cdot Y_\delta - Y_v\cdot N_\delta)} \tag{8}$$

$$\beta = \frac{\delta}{U\cdot C}\left[(m\cdot x_G\cdot U - N_r)\cdot Y_\delta + (Y_r - m\cdot U)\cdot N_\delta\right] \tag{9}$$

where δ is the rudder deflection angle, x_G is the longitudinal position of the centre of gravity and *C* is the stability on route parameter, calculated on the basis of the relation

$$C = Y_v\cdot(N_r - m\cdot x_G\cdot U) + N_v\cdot(m\cdot U - Y_r) \tag{10}$$

The condition of the course keeping ability is C>0.

By using the linear Abkowitz model, the computer code PHP Manoeuvrability [4] was developed at the Research Centre of the Naval Architecture of “Dunarea de Jos” University of Galati, in order to estimate the manoeuvring characteristics of the ship, in deep or shallow water conditions. Practical applications are performed in the next chapter, in the cases of three types of ships (supply vessel, river coaster and ferryboat).

3. PRACTICAL APPLICATION

The evaluation of the stability on route parameter (C) and of the nondimensional value of the steady turning diameter (STD/L_{WL}) was exemplified depending of the H/T ratio, for the cases of the supply vessel, river coaster and ferryboat having the same design speed, equal with 18 Km/h.

The main characteristics of the ships presented in Tables 1-3 constitute the input data of the computer code PHP Manoeuvrability.

The change of the stability on route parameter with H/T ratio is presented in Table 4 for the case of the supply vessel, in Table 5 for river coaster and in Table 6 for ferryboat.

Table 4. Supply vessel. Stability on route parameter

H/T ratio	Stability on route parameter C
∞ (deep water)	0.000278
3	0.000406
2.5	0.000476
2	0.000658
1.5	0.001542
1.2	0.003463

Table 5. River coaster. Stability on route parameter

H/T ratio	Stability on route parameter C
∞ (deep water)	0.000177
3	0.000260
2.5	0.000304
2	0.000416
1.5	0.000953
1.2	0.002309

Table 6. Ferryboat. Stability on route parameter

H/T ratio	Stability on route parameter C
∞ (deep water)	0.000084
3	0.000125
2.5	0.000147
2	0.000204
1.5	0.000491
1.2	0.001216

The correlation between the nondimensional value of the steady turning diameter (STD/L_{WL}) and the operating conditions (H/T ratio) are presented in Table 7 for the case of the supply vessel, in Table 8 for river coaster and in Table 9 for ferryboat.

Table 7. Ferryboat. Steady turning diameter (nondimensional values)

H/T ratio	Steady turning diameter STD/L_{WL}
∞ (deep water)	3.716
3	4.543
2.5	4.907
2	5.701
1.5	8.237
1.2	10.889

Table 8. River coaster. Steady turning diameter (nondimensional values)

H/T ratio	Steady turning diameter STD/L_{WL}
∞ (deep water)	4.038
3	4.766
2.5	5.070
2	5.717
1.5	7.754
1.2	10.255

Also, the diagrams of the nondimensional value of the steady turning diameter (STD/L_{WL}) in the shallow water and medium depth conditions are depicted in Figures 1-3, for the cases of the supply vessel, river coaster and ferryboat, respectively.

The following values of H/T ratio were used on the abscissa of the diagrams

Shallow water		Medium depth		
1.2 m	1.5 m	2 m	2.5 m	3 m

Table 9. Ferryboat. Steady turning diameter (nondimensional values)

H/T ratio	Steady turning diameter STD/L_{WL}
∞ (deep water)	3.766
3	4.508
2.5	4.834
2	5.554
1.5	7.956
1.2	10.858

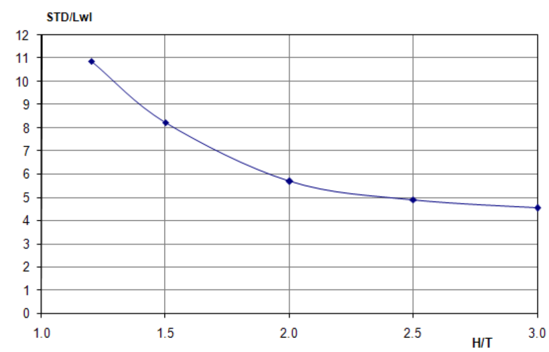

Figure 1 Supply vessel. Steady turning diameter (nondimensional values)

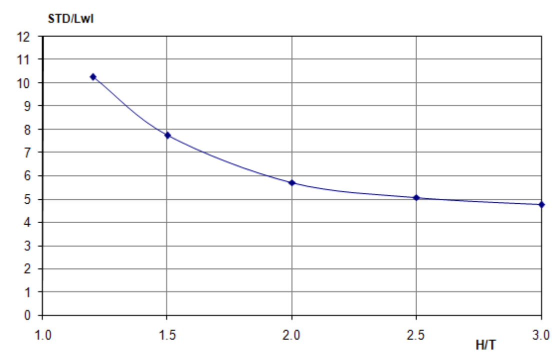

Figure 2 River coaster. Steady turning diameter (nondimensional values)

A comparative diagram of the nondimensional values of the steady turning diameter (STD/L_{WL}) in the shallow water and medium depth conditions, for the cases of the supply vessel, river coaster and ferryboat is depicted in Figure 4.

It can be seen that the minimum value of the nondimensional steady turning diameter in shallow water condition (H/T=1.2 … 1.5) was obtained for the case of river coaster. Also, the minimum value of the nondimensional steady turning diameter in medium depth condition (H/T=1.5 … 3) was obtained for ferryboat.

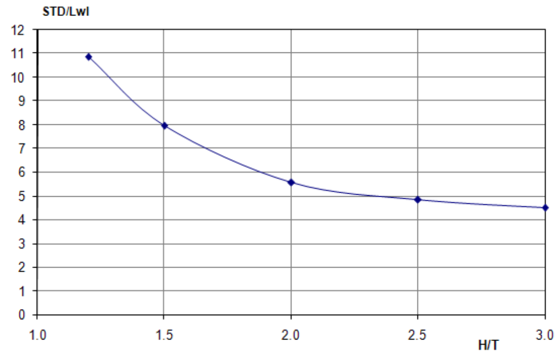

Figure 3 Ferryboat. Steady turning diameter (nondimensional values)

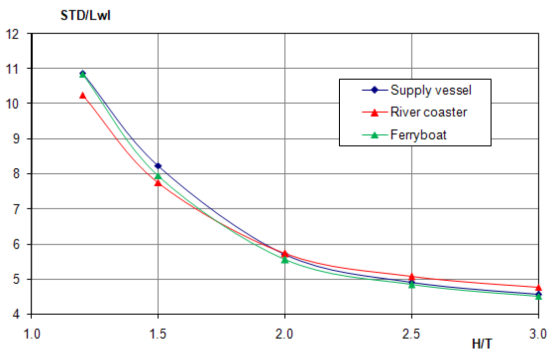

Figure 4 Supply vessel, river coaster and ferryboat. Comparative diagram of the steady turning diameter (nondimensional values)

4. CONCLUSIONS

The ship manoeuvring constitutes a very important hydrodynamics performance, related to the operating safety.

In the initial ship design phase, is necessary to quickly estimate the manoeuvring abilities with a good accuracy. As a consequence, software instruments must be developed in order to compute the ship manoeuvring performance.

Based on the Abkowitz linear mathematical model, the computer code PHP Manoeuvrability was developed in the Research Centre of the Naval Architecture Faculty from "Dunarea de Jos" University of Galati. This code was included into the PHP software platform (Preliminary Hydrodynamics Performance), dedicated to the initial ship design process.

The practical evaluation of the manoeuvring performance was exemplified for three types of ships (supply vessel, river coaster and ferryboat), in deep and shallow water conditions, at design speed (18 Km/h).

From the point of view of the ship manoeuvrability performance in deep water condition, the breadth to draught ratio (B/T) constitutes an important characteristic. Usually, if this ratio decreases, the ship stability on route increases.

For the cases of the analysed vessels, the values of the B/T ratio are presented in Table 10. It can be seen that, for the supply vessel having minimum B/T ratio, the maximum C parameter was obtained (Table 4).

Also, the rudder area influences the turning circle diameter in deep water condition. Usually, if the rudder area increases, the steady turning diameter decreases.

Table 10. Breadth to draught ratio

Ships	Breadth to draught ratio B/T
Supply vessel	2.684
River coaster	3
Ferryboat	2.993

In the cases of the supply vessel and ferryboat, having large rudder areas (3% from the wetted lateral area), the decreased values of the steady turning diameters were determined (Tables 7 and 9).

Related to the behaviour of the ships in shallow water and medium depth conditions, the following main observations may be noted:

- the analysed type of ships are stable on route (C>0);
- the maximum value of the stability on route parameter C was registered for the supply vessel (having the minimum value of the B/T ratio), both in shallow water and medium depth conditions;
- the large values of the nondimensional steady turning diameter were calculated in shallow water condition, for all types of ships;
- the minimum values of the nondimensional steady turning diameter were obtained at ferryboat (heaving the maximum value of the rudder area) in the case of the medium depth and for the river coaster in shallow water condition.

As a general conclusion, important increases of the steady turning diameter and of the stability on route parameter were identified, during the shallow water restriction. Obviously, the presented results must be validated on the basis of model experimental tests and full scale tests.

5. ACKNOWLEDGMENTS

The research was supported by the Research Centre of the Naval Architecture Faculty of "Dunarea de Jos" University of Galati.

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ANALYSIS ON THE OPERATIONAL RISK AT SHIPPING COMPANIES

[1]OLTEANU ANA-CORNELIA, [2]STÎNGĂ VIORELA-GEORGIANA

[1,2]*Constanta Maritime University, Romania*

ABSTRACT

Given the fact that the performing strategies of economic entities are including programs and procedures for risk management aimed at minimizing the likelihood of risks and the potential exposure, every company tries to achieve one central objective: gaining a higher profit for shareholders. This paper aims at presenting the methods needed for the assessment and the management of the operational risk, given that, until recently, this type of risk was not considered very important, assuming that it has a small impact on the economic activity. Taking into account the novelty of the operational risk in the economic activity, but also at the shipping companies, we have chosen this subject in order to propose new strategies for limiting it, especially at shipping companies, considering that its management is expected to become very important in the near future.

Keywords: *Operational risk, shipping company, strategies.*

1. INTRODUCTION

Over time it was concluded that the risk is a vital component associated with all economic activities, that cannot be fought but only managed, considering the fact that if we do not assume it, we may lose some earning opportunities, which means that a well-established risk may bring added value to the economic entity, representing a process where risk management becomes competitive strength. The risk management is the "art" of taking decisions and acting on the basis of insufficient data.

Given the complexity and the importance of transport as an essential component of the global economy, we can say that the debate on aspects of this broad field can always be considered current. It is important to take into account the large number of stakeholders involved in achieving these exchanges, including the owners (ship owners), the charterers (owners of goods), the maritime brokers, the shipbuilders and the financiers, working each year to achieve seas and oceans transport of more than 4 billion tons of goods, by addressing the shipping industry as more than a business.

We need to highlight the important role of maritime transport into the world trade, especially the need of very competitive and efficient shipping companies. The activities performed at their level must identify, plan and avoid risks. Studying and analyzing the operational risk is an important step that any shipping company should do, in order to ensure the safety by all points of view.

2. LITERATURE REVIEW ON RISK

From linguistically point of view, the risk was defined as the probability of happening for an event with adverse consequences for the subject. Over time, the risk definitions have been enunciated more general and the distinction between risks become difficult, thus generating various ambiguities and discrepancies.

So far the risk has been studied statistically, not revealing the "root cause" of production losses, in this situation being considered an external factor.

C.C. Kiriţescu and E. M. Dobrescu offered the most comprehensive definition of risk as "probable and future event whose achievement could cause some loss." D. G. Uyemura is trying to define and explain the risk based on the idea that "risk is the volatility of net cash flows of a business unit." Thus in maritime activity the risk is a general characteristic and its management is not translated only by minimizing the costs it might cause, but also by stabilizing incomes while playing the role of a shock absorber. In contrast, M. Rouche and G. Naullen define risk as a commitment bearing a given uncertainty, with a probability of gain or damage, the latter being degradation or loss.

Ulrich Doerig believes that "risk creates value and profit comes from taking risks" and Paul Getty thinks that "Where there is money come the risk".

In order to track, control and measure the numerous risks that any organization is exposed to, it must be conducted an inventory and a proper defining. Thus proper management of this phenomenon involves optimizing the risk-profitability pair, adapting performance indicators at risk.

After combining the distribution of frequency and severity of loss, the estimated average will provide the expected loss and from the difference between VaR by 99.9% and the expected loss will result the unexpected loss.

Specialty literature determined that the risk is essential associated component of all economic activities, which cannot be fought but only managed, considering that if not assumed any risks, opportunities to win can be missed. Any entity is seeking to maximize profits by managing specific risks in its field of activity and by avoiding or transferring the risk that it does not want to take. An efficient strategy of an entity must include programs and procedures for handling risks, aimed at minimizing the likelihood of such risks and potential exposure so as to achieve the central objective, namely obtaining a higher profit for shareholders. In reality may be encountered situations where the cost of implementing and operating procedures relating to the management of risk to be higher than the potential exposure to risk, or cases in which the company's strategy to involve assuming additional risks or new risks, so be as minimizing risks do not turn into an end in itself.

The company may face many risks which may or may not be controlled, but affecting financial condition, by the nature of the work they perform being the most affected by changing economic and financial conditions. In the financial area, risk should be treated as a conglomerate or a complex of risks, often interrelated, producing one can generate the chain production of the others.

The risk may itself have an impact (direct losses incurred) or induced (effects on customers, staff, partners, authority) important on the value of an economic entity. Thus we can define risk as the probability of occurrence of an event that has adverse consequences for the subject and the exposure to risk as the present value of all losses or additional expenses that the organization will/could have to bear.

3. ANALYSIS REGARDING THE OPERATIONAL RISK

Kuritzkes (Wharton, 2002) states that operational risk is a non-financial risk that comes from three sources: internal risk such as the risk arising due to rogue employees; external risk arising from uncontrolled sources such as terrorist attacks or natural disasters; and business risk as the most important.

Culp (2001) believes that operational risk is everywhere, but significant risks affecting the value of the institution have to be identified, which is very difficult because it is hard to distinguish them from the risk business and different companies are using different organizational processes to meet operational risk.

Karina Rosu defines risk as "potential variation from results of present actions or conditions ', being perceived by: the attitude towards risk, the degree of control over the risk, the degree of discretion with regard to taking or not taking the risk, responsibility for the risk, the variability of results.

Thus an event can cause: one or more internal losses; an incident without any financial impact (quasi-loss, reputation risk); or a combination thereof. Risk is the main phenomenon that an economic entity is facing, being the source of losses or even bankruptcy due to unforeseen difficulties encountered in carrying out the activity.

Before the 90's the operational risk was considered unimportant, until generating operational risk events have caused significant damage that required reorganization, improving the management and focusing on controlling the business environment.

Operational risk can be defined as an area characterized by a low frequency and predictable events such as processes and systems errors, accompanied by a high loss every 10 years, like serious systems errors, destruction of assets etc. Currently these high losses have become more common and more visible in the media industry.

Pyle (1997), Doerig (2000) believes that operational risk is the cost of non-execution of the proper activity referring to a large area[1], like a division of this risk into two components, the risk of operational failure and the strategic operational risk[2], ranging from incorrect trading and accounting errors to terrorist activities and discounts, improper sale practices and system failures, violations of regulations, and events due to natural disasters.

Operational risk is the improper or the inadequate impact[3] over the institution's work resulting from the acts or negligence in the conduct of business, mostly from processing transactions, which are determined by inappropriate human behavior, fraud, lack of appropriate procedures, processes or monitoring, failure of technology, projects, management systems, operating disruptions, structures of execution, disasters or other external events.

The PNC Financial Services Group[4] (2001) recommended the use of a more concise definition of operational risk, which is mainly based on direct losses and excludes categorically the business risks, strategic and reputational, as: "Operational risk is the risk of direct loss of revenue from domestic events related to inadequate staff, serious errors or illegal behavior, due to errors or inadequate processes, systems or from external events".

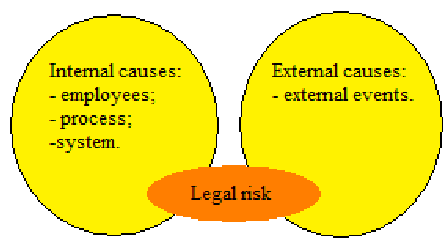

Figure 1 The causes of legal risk
Source: BCBS[5]

With the onset of global financial crisis the risks specific to economic activity were manifested more intensely, so that incidents such as operational risk losses caused important damages, thus becoming justified the interest in operational risk management, whose meaning requires new practical approaches.

The operational risk management involves creating a system of internal control and prevention, rather than relying on quantitative methods that can easily determine the frequency, severity and impact of certain factors.

Operational risk is specific to each entity, being difficult to know the internal problems, to collect general information about the generated losses and also being unable to get universal information through a simple summary of the facts. Using statistical methods is

[1] Croughy, M. et.al. (2001),
[2] Marshall, Ch., (2001)
[3] Erich, R. (2008)
[4] Keller, J.S. (2001)
[5] Guidelines on Operational Risk Mangement

difficult to implement due to the low representation of data as high operational losses are hardly ever produced (they are located outside the confidence interval, in the "tail" of statistical distribution) thereby a universal management of this type of risk it is not possible.

In terms of operational risk, the firms must face important challenges when building a proper measurement model, due to the identification and quantification of loss-generating events difficulties. So they must employ trained staff, to improve the technological process and to appeal to institutions specialized in this area, which involves the spending of a large amount of money, in order to use the methods for sizing the operational risk in case of nonexistence of the complete database and a flexible informational system.

The multitude of loss events due to operational risk was highlighted in the present work by stating that an event may cause more associated losses and so is necessary to identify the basic event.

The risk is not assumed by an economic entity as a thing that happens but as a continuing "fight", being measured by the likelihood and impact of negative output.

Terms of acceptance or refusal of the risk are reflecting the economic entity's ability to assume risk and its attitude towards risk. Acceptance of unexpected loss is determined by economic factors, social and psychological.

Thus among the features of this definition we can enunciate: the attention is fixed on the internal aspect; a decisive role is given to the people and their committed errors by self-interest and / or ignorance- there are three types of operational risk in this context: hazard, errors and conflicts; the importance given to the processes is placing this risk management very close to the quality management of the institution; the external incidents are natural, political or military events, losses and deficiencies in the technical infrastructure and also legal, regulatory and tax changes.

The internal control system plays an important role, the elements and the accepted rules have been overlooked during periods of restructuring and innovation, thus multiple losses could have been avoided or reduced if the established rules were respected.

A loss from an operational risk can result only from a characteristic event of this risk, which is an incident following a business process, except for the strategic and discretionary process. There were found several losses associated with an event, so the research of base event[6] is justified, ORX Association[7] recommending that:

- Repeated mistakes to be considered separate events if they are produced by misunderstanding, lack of training or inadequate control etc.;

- Repeated mistakes arising from failure of model, of business process or due to failure of a product to be considered a single event; these events are triggered by retrospective changes of laws or their interpretation;

- Multiple compensations to clients are considered unique events if there is a fundamental joint statement regardless of the cases resolution;

- Multiple impacts of a mistakes to be considered a single event;

- Independent losses due to a joint action plan to be considered as a unique event.

Operational risk can be interpreted also as a weakness of the economic entity which can be reduced or minimized by increasing controls.

Operational risk is the risk of loss[8]:

- Direct loss due to operational failure covering following losses: from regulation, resulting from the systems failures, documentation problems or changing fees, errors into entries or results from increased expenses affecting the operations profitability. Thus incorrect determination of the entry prices affect the price of goods or services; from data entry errors can result erroneous payments; inadequate documentation can lead to incorrect cash flows or mistakes in calculating the cover, incorrect data about the market can lead to incorrect pricing etc.

- Indirect loss connected to the impact of this risk over the other risks.

Following this idea are given some examples: if input data is wrong may result incorrect estimations; incorrect confirmations can introduce errors in coverage; in case of system failure is impossible to monitor economic activity.

Operational risk is viewed as a common risk, but the most dangerous type of risk[9] because it is an idiosyncratic risk and depends largely on the type of company and market, which means that there are no standard procedures and the relevant data for operational risk and related management are very complex[10]. Operational risks are very difficult to manage due to their complex interdependence, meaning that the reduction of operational risk can have an undesirable effect on other risks.

Lack of a clear definition for this risk has created the possibility for economic agents to analyze all categories of operational risks, including the risk of: fraud, process personal, marketing control, reputation, security, liquidity, takeover, transfer, bankruptcy, using improper methods and formulas, non-performing systems, legal, technological, regulatory change, the occurrence of natural disasters etc.

The operational risk occurs due to four factors[11]: the internal processes, the human's risk, the system's risk and the external events.

- The internal processes generate losses due to: failed transactions, regulations or customers. The errors may occur due to unauthorized access, loss of client assets, the wrong introduction or execution of a transaction, inadequate accounting records etc.
- The human risk generates losses due to employees or it may affect the company's

[6] determining the initial incident without which the other would not be produced

[7] ORX Association (2007)

[8] De Satyajit Das (2006)

[9] Williams, R. (2006)

[10] Power (2003)

[11] Burchett, P. and Cagny, D.W. (2001)

relations with the authorities, the customers or third parties, as internal fraud, problems with recruitment and retention of staff, unauthorized transactions,, disease and injuries of employees, etc.

- The systems' risk[12] is a natural consequence of an over development business, that may generates losses concerning the business or other systems due to infrastructure or IT. So, the errors in this case could software or hardware errors, systems failures, access to information security or to unauthorized systems, piracy, viruses, unavailability of systems and data integrity etc. The main causes are: design, poor performance, missed replacements, misuse etc.
- The external events generate losses due to third party such as external loss or destruction of assets, different variations of the regulations that affect the company's activity, such as terrorism, natural disasters, fraud, fire etc.

According to a survey made by RMA the most widespread losses due to operational risk[13] are the ones that came from the internal processes (65%), followed by those due to the human factor (26%), to the external events (7%) and to other systems (2%).

The literature defines the operational risk as the risk of incurring losses due to:

- unexpected internal control weaknesses;
- deficiencies of the information systems caused by human errors;
- system's crashes;
- system control.

An economic entity should classify their losses in three categories[14], namely:

- an expected loss that will be absorbed by net profit, it can be incorporated into the price of the transaction that generated it;

- an unexpected loss that will be covered by risk reserves (so not entirely unexpected);

- an extreme loss that requires basic capital or insurance/reinsurance coverage.

Currently many economic agents are making differences between: the controllable risks (that are risks in which the company's shares can influence the outcome, they can be covered normally without resorting to a third party) and uncontrollable risks (that are risks that cannot be internally controlled, they can be covered by: the insurance against natural disasters, the funding obtain from a third party etc.).

In 2002 Ebnöther, Vanini, McNeil and Antolin defined quantitative operational risk for a set of manufacturing processes as risk transactions over a certain amount. The cost related to the definition of processes can be very high if all processes require definition, if the definition is made at a deep level of aggregation or if they are not characterized by stability over time.

[12]Santomero (1997)
[13]Harmantzis, F. (2003)
[14]Coleman, R. (2010)

The operational risk includes many facets of business risk[15], but many definitions do not include business cycles and fluctuations in income taxation.

The losses obtained from operational risk manifestation are not readily disclosed because of reputational damage, these risks being directly dependent on the management quality with effects on: the customer satisfaction, the company reputation and the reward shareholders.

4. STRATEGIES FOR LIMITING THE OPERATIONAL RISK FOR SHIPPING COMPANIES

Strategy for limiting the operational risk for shipping companies may include: staff training; ensuring the effectiveness of internal control systems; continuous adaptation of normative documents on legal regulations and market conditions; strengthening the security systems; continuous estimation regarding the benefits and costs that result from the reduction of risks; measures taken to limit or minimize the incidents of operational risks; continuous pursuit of risk reduction in order to see if the reduction is real of it the risk moved to another company activities; outsourcing risks; continuous update, evaluate and test of the business continuity plans.

Depending on the risk profile, in order to reduce the risk the company can use one of the following strategies:

- the risk acceptance (this strategy is taken if the risk is insignificant, so there are not required any measures);
- the risk reduction (in this case there is a process of reorganization on the company that will reduce the frequency and severity of operational risk events);
- the risk transfer (this strategy implies outsourcing risks);
- the risk avoidance (in this case the activities that generate risks are stopped in order to establish the possible losses and their prevention).

The methods adopted in order to reduce the risk depend on the available resources, the cost associated to risk reduction and also on time needed for the implementation processes.

Studies have shown that is impossible to find an optimal solution for managing this type of risk, but at least the shipping company should ensure the following components: a database, adequate tools regarding the operational risk and management reports.

Many shipping companies have paid attention to operational risk events, while undertaking measures to reduce them like:

- achieving normative documents according to actual regulations and market conditions;
- providing trainings in order to reduce operational risk exposures;
- verifying the risk reduction methods adopted by the shipping company to identify its usefulness;

[15] Carey, M.S. and Stulz, R.M. (2006)

- collecting and reporting the events that generate losses;
- using additional methods to reduce risk, such as insurance policies or outsourcing;
- assuring a permanent assessment in terms of costs and benefits of risk reduction methods;
- developing new information systems in order to improve the security etc.

5. PROPOSALS ON OPERATIONAL RISK MANAGEMENT FOR SHIPPING COMPANIES

After the description of the operational risk and after setting some strategies regarding its reduction, we have highlighted a number of proposals that could help shipping companies like:

- practicing prudent policies regarding the human resources;
- developing psychological climate that ensures protection and verification of employees;
- conducting physical checks;
- eliminating conflicts of interest;
- identifying alarm signals at company's departments;
- verifying the customers' identity;
- assuring personnel with specific training for guard and security;
- using technical and programmed means in order to ensure the protection and confidentiality of information;
- using special technical means to ensure continuous electricity;
- testing and monitoring information systems;
- installing a server backup performance for continuous operation of the automated system;
- carrying out cross inspection for identifying fraud;
- changing periodically the passwords of computer system;
- using an unitary information system that provides the management of customers database;
- making the correlation between the identified events and their impact;
- achieving internal control;
- achieving real reports;
- using technical means for limiting access to the information system;
- training of personnel;
- using back-up system for IT systems that ensures the relaunch of some strategic operations;
- create and implement a business continuity plan in crisis conditions;
- making quantitative assessment of operational risk in each transaction, activity, or product;
- using a database containing information for a period of at least five years, ensuring maximum efficiency and decentralization of the internal control in all structures of the shipping company.

According to our study we can suggest to the economic agents as the first step that they should make in order to manage and to measure their operational risk, to conduct an inventory by category so that they can create methodologies needed to identify, plan and avoid these risks. The shipping companies should also develop plans for crisis situations to remedy the effect of this type of risk.

There have been formulated more opinions worldwide on operational risk and how to size it. The main advantage of any economic entity, given the current state of the world economy, is ensuring safe from all points of view.

6. CONCLUSIONS

Nowadays the business world is characterized by uncertainty, complexity and ricks. In our view, any economic entity is responsible for all the specific risks arising as a result of searching for profit, in compliance with prudential measures. The exposure to risk is justified by the forecasted results, so that the financial situations are not significantly influenced by the possible losses that can be cover by the provisions made or by the profit. The risk sizing should be made so that the production loss to be acceptable and do not affect the company's image.

We may conclude that the identification, the evaluation, the analysis and the management of operational risks can be achieved either by:

- top-down methods (from top to bottom, this method handles this risk regarding the consequences and it allocate reserves to cover losses, for example the sum of losses due to employee error, the irregular functioning of the information system etc.)
- bottom-up methods (from the bottom to top, this method analyze the causes of losses from operational risk).

In conclusion, the operational risk involves financial loss to the shipping companies, which occur due to internal and external events that are not able to be prevented thru internal control systems, policies, organization, ethical standards or other controls and standards of the company.

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DESIGN OF A PRIMARY CLARIFIER FOR SEDIMENTATION PROCESS IN A WASTEWATER TREATMENT PLANT

PARASCHIV LIZICA-SIMONA

"Dunarea de Jos" University of Galati, Romania

ABSTRACT

In this paper an analytical study has performed to determined variation of the terminal settling velocities, of the spherical particles in water. Settling of particles has governed by density of fluid, size, shape and density of particles. For a spherical particle settling in a Newtonian fluid in the laminar flow regime, the settling velocity is given by Stokes equation.

Keywords: *sedimentation, particle settling, settling velocity, wastewater.*

1. INTRODUCTION

Untreated wastewater contain materials which will either float to the water surface or settle to the bottom of clarifier when the wastewater velocity has reduced to become very slow. In most municipal wastewater treatment plants, the treatment unit which follows the grit channel is the sedimentation and flotation unit. This unit has called a settling tank, sedimentation tank, clarifier or the most common name is primary clarifier.

Clarifiers are settling tanks used for continuous removal of solids particulates or suspended solids from liquid by sedimentation.

The inlet flow velocity of wastewater introduced into clarifier has reduced to maximize the hydraulic retention time inside the clarifier and to avoid excessive turbulence which will lead to a better sedimentation.

Another important issue is the entering distribution of water into the decanter, which has distributed evenly across the entire section of the sedimentation area inside the clarifier to further reduce mixing and increase the retention time to allow the particles to settle.

The basis design of a wastewater decanter largely depends on the basin surface and water retention time in the decanter.

The removal efficiency of solids present in wastewater was calculated mainly based on the assumption that all particles have the size, density, specific gravity and forms uniform. However, in reality, such condition does not exist and solids from wastewater will sometimes be highly dispersed and so the settlement time will be greater and this must be taken as the main consideration in the design.

2. SEDIMENTATION

Sedimentation is one of the most basic processes of water treatment. Plain sedimentation, such as the use of presedimentation basin and sedimentation basin following coagulation – flocculation, is the most commonly used in water treatment facilities. Sedimentation is a solid—liquid separation by gravitational settling. There are four types of sedimentation: discrete particle settlings, flocculants settling, hindered settling and compression settling. The terminal settling velocity of a single discrete particle has derived from the forces (gravitational force, buoyant force and drag force) that act on the particle. The classical discrete particle settling theories have based on spherical particles. The equation has expressed as:

$$u = \sqrt{\frac{4g\left(\rho_p - \rho(T)\right)D}{3C_D\rho}} \quad , \tag{1}$$

where:
u - settling velocity of particles, [m/s];
g - gravitational acceleration, [m/s2];
ρ_p - density of particles, [kg/m3];
ρ - density of water, [kg/m3];
D - diameter of particles, [m];
C_D - coefficient of drag.

The values of drag coefficient depend on water density (ρ), relative velocity (u), particle diameter (D) and viscosity of water (μ), which gives the Reynolds number Re as:

$$\mathrm{Re} = \frac{\rho(T)uD}{\mu} \tag{2}$$

The value of C_D decreases as the Reynolds number increases. For Re less than 2, C_D has related to Re by the linear expression as follows:

$$C_D = \frac{24}{\mathrm{Re}} \tag{3}$$

At low values of Re, the settling velocity is:

$$u = \frac{g\left(\rho_p - \rho(T)\right)D^2}{18\mu} \quad . \tag{4}$$

This expression is known as the Stokes' equation for laminar flow conditions.

In the region of higher Reynolds numbers (2 < Re < 500), C_D becomes:

$$C_D = \frac{24}{\mathrm{Re}} + \frac{3}{\sqrt{\mathrm{Re}}} + 0,34 . \qquad (5)$$

In the turbulent flow region (500<Re<200000) the C_D , remains approximately constant at 0.44. The velocity of settling particles results in Newton's equation:

$$u = 1,74\sqrt{\frac{\left(\rho_p - \rho(T)\right) gD}{\rho}} . \qquad (6)$$

When the Reynolds number is greater than 200000 the drag forces decreases substantially and C_D becomes 0.1. No settling occurs at this condition.

$$\rho(T) = 1000(1 - (T+288.9414)/ /(508929.2*(T+68.12963))*(T-3.9863)^2) ,.(7)$$

$\rho(T)$ = density as a function of temperature, [kg/m^3],

T = temperature, [K].

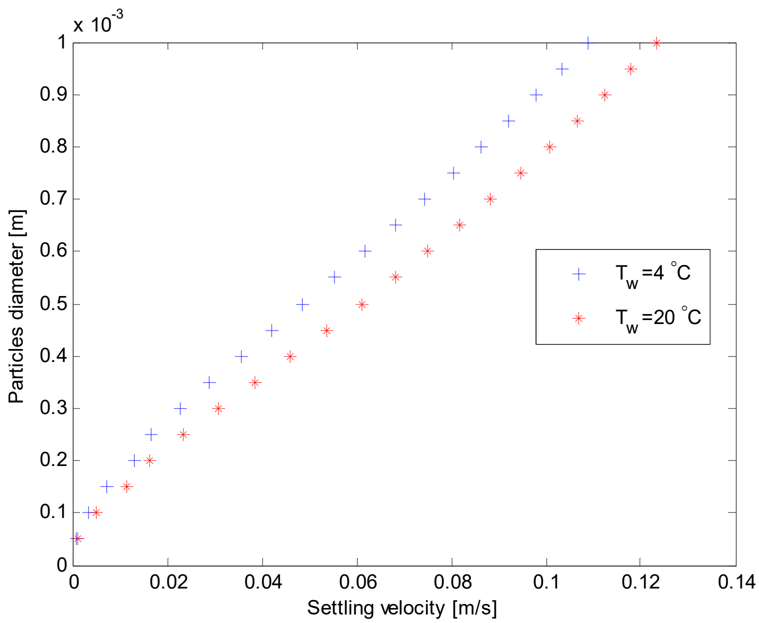

Figure 1 Relationship between settling velocity and sand particles diameter

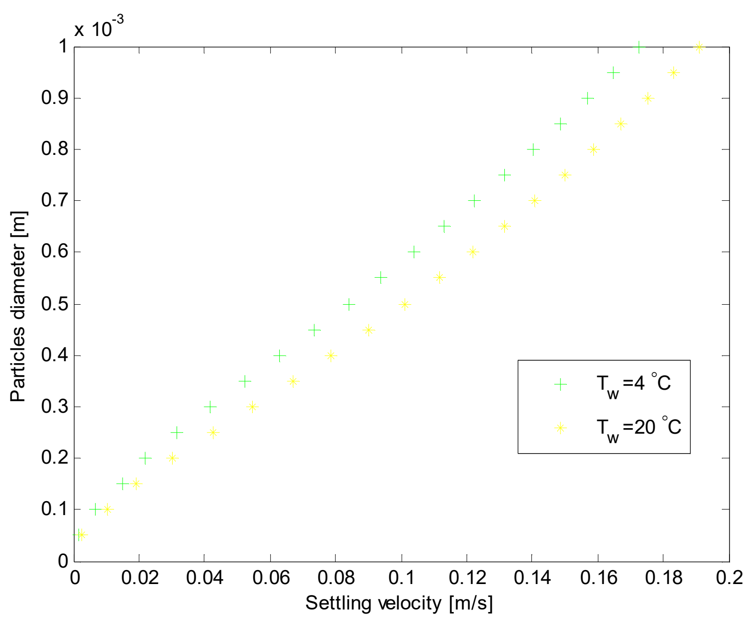

Figure 2 Relationship between settling velocity and iron oxide particles diameter

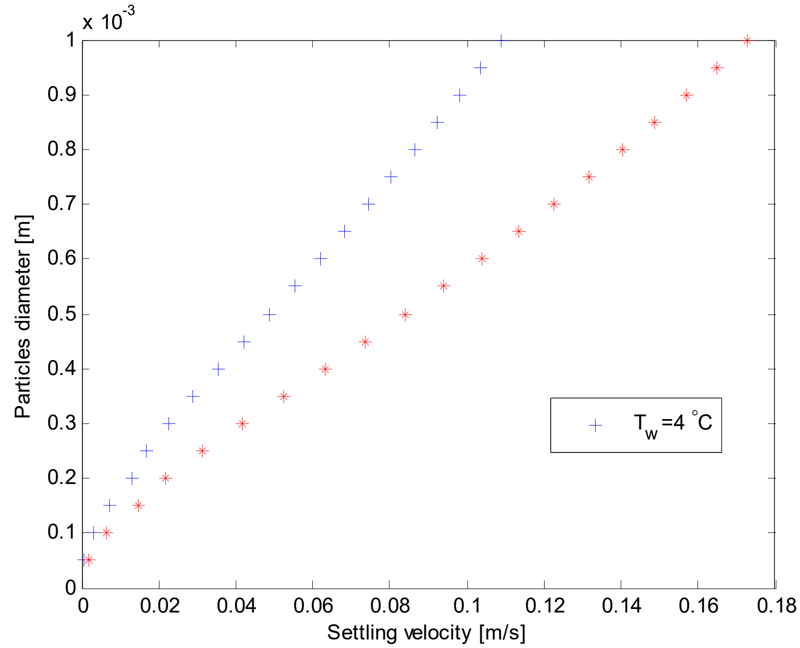

Figure 3 Settling velocity for sand and iron oxide particles diameter

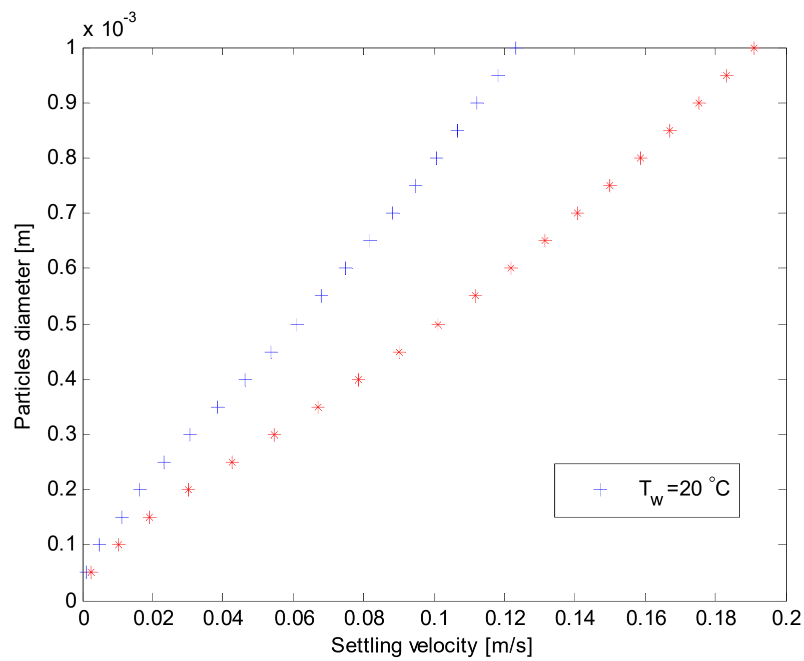

Figure 4 Settling velocity for sand and iron oxide particles diameter

The graphics show the fall speed, or settling velocity, as function of particle size for particles of sands and iron oxide.

Figure 1 show the relationship between settling velocity and sand particles diameter, for different water temperatures, 4°C and respectively 20°C.

In Figure 2 was determined the relationship between settling velocity and iron oxide particles diameter, for different water temperatures, 4°C and respectively 20°C. We can notice that the settling velocity in this case is higher because of influence of particle density which are higher too.

We can notice that dust particles with diameters less than 0.2 mm fall at a speed of about 10 mm/s. Particles larger than 0.2 mm in diameter fall disproportionately faster: 0.5 mm particles fall at about 48 mm/s. Particles smaller than 0.2 mm settle very slowly. 0.10 mm particles fall at only 3 mm/second while 0.05 mm particles fall at only 0.8 mm/s, so the finest particles settle so slowly that they has transported across settler without settling.

In Figures 3 and 4 has compared the settling velocity for those two types of particle.

3. CONCLUSIONS

Knowledge of the terminal settling velocity of solids in liquids has required in many industrial applications. The fall velocity depends on the density, viscosity of the fluid, and the density, size, shape, and surface texture of the particle.

For particles smaller than 0.2 mm we can see that influence of water temperature, respectively influence of water density is smaller but as the diameter of particles increase the influence are getting higher.

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THE DEVELOPMENT OF THE MODEL OF THE PROJECT TEAM BEHAVIOR BY MEANS OF THE MARKOV'S CHAIN

Olga Sherstyuk

Odessa National Maritime University, 34, Mechnikov str., 65029, Odessa, Ukraine

ABSTRACT

Based on the Drexler and Sibbet's model of the team behavior that includes 7 stages of the formation and operation of the project team, the model of forming the project team is proposed. The Drexler and Sibbet's model of the team behavior is presented in the form of the Markov's chain, where each stage of forming the team behavior is provided as a graph of transitions from one state to another, where transition probabilities to other states are indicated, as well as the probabilities of saving the current states. This matrix reflects the state of the system, in which the preconditions of success of states as a degree of excellence of the project team during its operation are formed. The matrix of transition probabilities is generated on the basis of time costs spent at each phase of the forming and operation of the project team. Two options of the team behavior are studied: a basic variant of the team behavior and the team behavior after the introduction of the adaptive learning system. Applying the adaptive project system is bilateral. On the one hand, the educational system represented by the project team and teaching staff with its methods, forms, content and technologies is actively adapted to the individual characteristics of one team member. On the other hand, the team member is adapted to this system, bringing qualitative changes occurring in his physiological and social characteristics that affect the outcome of project activities. The study shows the change of probabilities of states through the introduction of in-depth knowledge and adaptive learning. The proposed model allows to quantify the present course of project processes as a result of changes in the project team and time costs caused by problems that both each member and the whole team will face at seven stages of cooperation.

Keywords: *adaptive learning system, Markov's chain, project team, team behaviour.*

1. THE URGENCY OF THE PROBLEM

Teamwork is one of the skills that today is highly regarded in the professional environment of the project, due to the implementation of various personal and interpersonal skills. The project manager and the functional units involved in the creation of the project, at this stage of the formation of the team have to solve a number of specific tasks related to labor motivation, conflict, implementation, control, responsibility, communication, power, leadership, etc. This creates favorable conditions for work, helps to overcome the enormous mental stress arising in the course of the search, negotiation and implementation of project solutions, avoids conflict and stress, which ultimately affect the scientific and technical level and quality of the project.

Novelty, uniqueness, risk and transience - all these features are inherent in the new project, they also determine the difficulty in the formation of the team. Creating a team for a new project is complicated by the fact that these people did not work together, did not have common values and norms, but need to work effectively and synchronously. It takes much time to reach a sense of team within the group, to establish common norms, standards and values. For the project to be successful, the grouping of people has to happen before the team starts to work "at full capacity".

The strategic goal of the project is the main factor of creating and integrating activities of the team. In the process of achieving the objectives of the project team takes on its borders using organizational capabilities and resources of the project participants. The project team acts as a social organism, having its origin, performs vital functions (project management) and ends its existence with dissolution or transformation into another management team.

On the one hand, the project team affects the creation of a specific organizational project environment, creating values, principles and rules of conduct for staff. On the other hand, they act in it subjecting to a common goal and project management philosophy.

Therefore, the problem of the formation and activities of the project team are appropriate to consider in a logical sequence.

Currently, the effectiveness of teamwork is evaluated on the basis of goal setting, interpersonal, competency [1], and role-based approach [2].

Qualifications and competence of each of the candidates, as well as their requirements, are characterized by a plenty of factors that are difficult to imagine in the form of a mathematical model. As a rule, the manager takes the important personnel decisions on the basis of their experience and intuition. To solve this problem successfully it is necessary to perform an evaluation at each stage of the project team with the use of the approaches mentioned above.

2. BASIC MATERIA

Combining these approaches can be presented as the Drexler and Sibbet's model (Figure 1), which shows that the team is a dynamic structure, and movement at the stages occasionally happens to all the team and individual participants. At each stage of the project participants ask themselves the most important question and face a certain set of unresolved problems. The effectiveness of teamwork in various stages can be solved by approaches mentioned above (Table 1).

Table 1: The applicability of the approach of evaluating the teamwork effectiveness at different stages of formation

Approach	Stages of teamwork
Competence	Orientation, commitment, high productivity
Goal setting	Orientation, clarifying the aim
Role-based	Role assignment, high productivity
Interpersonal	Orientation, gaining confidence, update
Problem-oriented	Orientation, clarifying the aim, commitment

The team development is a continuous process; so multistage recursion is typical for the model. If the answer to the main question is not found at any stage, there is a return to a previous stage.

In the orientation stage of a new project the project team member asks himself the question "What am I doing here?". If the answer is more or less clear and happy, the participant asserts a desire to start working together. Initially he is introduced to the staff and in the course of business, supported, because he has a feeling of comradeship. If there is no answer, the participant is disoriented, afraid, feeling uncertain.

Caution (which prevents actions), lack of confidence and dilettantism are typical difficulties of the stage of gaining confidence which are predictably encountered by team members and team leaders in their professional development. If the answer to the question "Who are you?" is satisfactory for the participants, mistrust is overcome and relationship turns to a stage of trust and reliability.

In the phase of clarifying the aim the staff and team have overcome initial disorientation and try to understand the nature of their activities better. If the answer to the question "What do we do?" is not found apathy, skepticism and unhealthy competition are spread in the group. If the answer is found, there are clear objectives and a common perspective.

At the stage of commitment awareness encourages team members to look for weaknesses in work, to optimize processes. If the agreement on planning is achieved, roles are more or less assigned, solutions are clear. If the question "How are we doing it?" remains open, there are arguments between those participants who seek to innovate, and those ones who are satisfied with the status quo.

"Who, how, what, when?" is the cloud of organizational issues that requires to do a clear role differentiation. If everyone in the team got the answers to the questions "who, how, what, when?", processes are clear and the execution is disciplined. If not, and no response is given, omissions of deadlines, confusion in affairs and conflicts are inevitable

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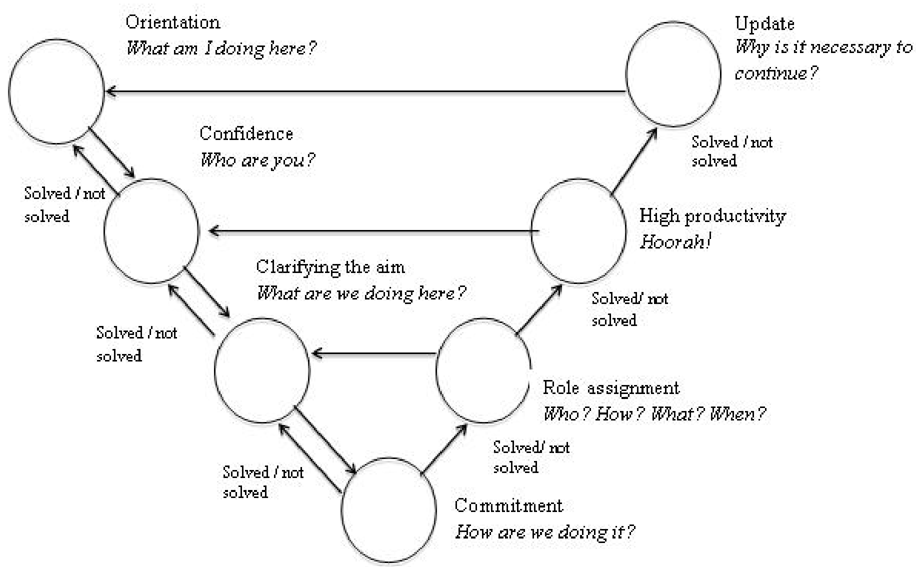

Figure 1 The Drexler and Sibbet's model of the team behavior

If the project team members achieve high productivity, synergy and spontaneous interactivity emerge in the process of operation. If high performance is not achieved, the disharmony and overstress are spread in the team.

At the stage of update team members are faced with the necessity to find motivation and new goals, to answer the question "Why is it necessary to continue?". At this stage it is likely that long working team members can be bored, plunge into reflection and experience failure. If the answer is found, the team is getting stronger, joint leisure and mutual respects unite them even more.

In the process of forming a team behavior there is a relationship of random change of states S_i *{i = 1, ..., 7}* at time *t* [0, T]. The value $i \in \{1, ..., 7\}$ is possible as random process S_i (t). If there is factor *t* in the range [0, T], the probability *P* {s-z <S (t) <s + z} ≥ 0 for any z> 0 [3]. The Markov's chain reflects this sequence. The Markov's feature of the team behavior is confirmed by the fact that:

- both forming a team behavior at different stages in the Drexler and Sibbet's model and in Markov chains the probabilities of the system states are possible to be changed by steps *k*;
- there are probabilities of transitions in other states;
- the sum of transition probabilities of any state is equal to 1;
- the sum of probabilities of all states at each step is equal to 1 as well;
- there is a similarity of topological structure of transitions [3].

The matrix of transition probabilities enables to forecast states of forming the project team a few steps forward, depending on certain changes. To achieve that, it is necessary to set the action appropriate to certain probability π_{ij} in the matrix of transitions to assess changes of teamwork success due to changes in the project team.

In Figure 2 seven stages of team behavior of the Drexler and Sibbet's model are presented as a graph of transitions from one state S_i to other S_j, where we denote the probabilities of transitions to other states, as well as the probabilities of saving the current states: S_1 - orientation; S_2 - confidence; S_3 - clarifying the aim; S_4 - commitment; S_5 – role assignment; S_6 - high productivity; S_7 – update.

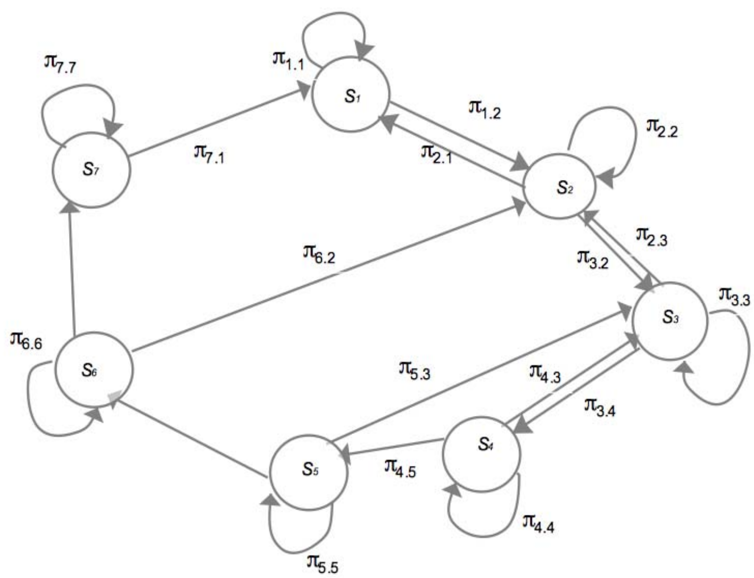

Figure 2 The markup graph of the state change of the team behaviour model

On the basis of the matrix of transition probabilities, provided that the initial state of the system is known, the probabilities of states $p_1(k), p_2(k), \ldots p_7(k)$ can be found after each *k*-th step of management actions on the system. The steps refer to a set of measures implemented in the project, activities that change the indicators S_i.

At any moment of time (after any k-th step), the system can be in one of *n* states:

$$\boldsymbol{S} = \{s_1, s_2 \;., \quad s_n\}. \tag{1}$$

Thus, one of the incompatible events of the complete group is fulfilled: $\{S_1(k), S_2(k), \ldots, Sn(k)\}$, where *k* is a step number of management actions on the system [3].

The probability of events after the *k*-th step is identified:

$$p_1(k)= \psi(S_1(k));\ \ p_2(k)= \psi(S_2(k));\ldots p_n(k)= \psi(S_n(k)). \tag{2}$$

For each *k*-th step the expression is equitable:

$$p_1(k)+ p_2(k)+ \ldots + p_n(k)=1, \tag{3}$$

as $p_1(k), p_2(k), \ldots, p_n(k)$ are the probabilities of incompatible events that form a complete group of events.

The values $\{p_1(k), p_2(k), \ldots, p_n(k)\}$ are the probabilities of states of the homogeneous Markov's chain with the discrete time in which π_{ij} transition probabilities do not depend on the number of the step. For any step *k* there are also the delay probabilities of the system in this state. In the graph (Figure 2.) arrows are affixed only to those transitions, which transition probabilities are not equal to zero. Delay probabilities π_{ii} complement the sum of transition probabilities for all transitions from this state to "one" [4].

Implementation of processes of interaction of the state S_1 with other states lasts for a time. The total time of the system being in state S_1 can be identified as:

$$T_1 = t_{1.1}+ t_{1.2}\ ; \tag{4}$$

where $t_{1.1}$, $t_{1.2}$ – time or duration of the system being in state S_1.

The intervals of time are converted to frequency:

$$\begin{cases} \pi_{1.1} = \dfrac{t_{1.1}}{T_1} \\ \pi_{1.2} = \dfrac{t_{1.2}}{T_1} \end{cases} \quad (5)$$

From the expression (4) taking into account the expression (5) follows:

$$\pi_{1.1} + \pi_{1.2} = \frac{t_{1.1}}{T_1} + \frac{t_{1.2}}{T_1} = 1. \quad (6)$$

Expression (6) represents a significant feature of any state - all transitions from state S_1 are the complete group of events for which the probability of their occurrence is equal to "one".

These features of transitions between states of the Markov's chain are equitable for all other classes (Figure 2).

State probabilities *p1 (k), p2 (k), ... p4 (k)* of the homogeneous Markov's chain with discrete time describing the phenomenological property of the system is the thing, with which object manifests itself. The matrix reproducing the system structure with transition probabilities $\pi_{ij} > 0 \ \{\forall \ (i, j) \in (1, 2, ..., m)\}$ can be written in the following form for the Markov's chain:

$$\begin{Vmatrix} \pi_{11} & \pi_{12} & 0 & 0 & 0 & 0 & 0 \\ \pi_{21} & \pi_{22} & \pi_{23} & 0 & 0 & 0 & 0 \\ 0 & \pi_{32} & \pi_{33} & \pi_{34} & 0 & 0 & 0 \\ 0 & 0 & \pi_{43} & \pi_{44} & \pi_{45} & 0 & 0 \\ 0 & 0 & \pi_{53} & 0 & \pi_{55} & \pi_{56} & 0 \\ 0 & \pi_{62} & 0 & 0 & 0 & \pi_{66} & \pi_{67} \\ \pi_{71} & 0 & 0 & 0 & 0 & 0 & \pi_{77} \end{Vmatrix} \quad (7)$$

Calculating the probability distribution at the next *(k + 1)* step is performed by the well-known formula of the total probability [4]

$$\begin{Vmatrix} p_1(k+1) \\ p_2(k+2) \\ p_3(k+3) \\ p_4(k+4) \\ p_5(k+5) \\ p_6(k+6) \\ p_7(k+7) \end{Vmatrix} = \begin{Vmatrix} \pi_{11} & \pi_{12} & 0 & 0 & 0 & 0 & 0 \\ \pi_{21} & \pi_{22} & \pi_{23} & 0 & 0 & 0 & 0 \\ 0 & \pi_{32} & \pi_{33} & \pi_{34} & 0 & 0 & 0 \\ 0 & 0 & \pi_{43} & \pi_{44} & \pi_{45} & 0 & 0 \\ 0 & 0 & \pi_{53} & 0 & \pi_{55} & \pi_{56} & 0 \\ 0 & \pi_{62} & 0 & 0 & 0 & \pi_{66} & \pi_{67} \\ \pi_{71} & 0 & 0 & 0 & 0 & 0 & \pi_{77} \end{Vmatrix}^T * \begin{Vmatrix} p_1(k) \\ p_2(k) \\ p_3(k) \\ p_4(k) \\ p_5(k) \\ p_6(k) \\ p_7(k) \end{Vmatrix} \quad (8)$$

where T –is a sign of transposing the matrix.

By changing π_{sj} the system can be moved to any stage of forming the project team. For example, if each member of the project team spends almost all the resource of time for himself at the orientation stage corresponding to S_1, the value $\pi_{1.1} > 0,8$ will correspond to the greatest resource cost in the time. The guidelines for determination of transition probabilities according to the ratio of used resources in time for the various stages of forming the project team according to the Drexler and Sibbet's model are shown in Table 2.

Table 2: Determination of the values of transition probabilities

Character communication $i \to j$ according of resource cost in the time	The value of transition probabilities π_{ij}
The process takes most of the time resource	*0,75 – 1,0*
Average of resource time costs	*0,25 – 0,75*
Lower spending time	0,1 – 0,25
Low cost of resource time	0 – 0,1
No time resource spending	0

The matrix of transition probabilities for the basic version of the project determined on the basis of expert assessment may look like:

$$\|\pi_{ij}\| = \begin{Vmatrix} 0,5 & 0,5 & 0 & 0 & 0 & 0 & 0 \\ 0,15 & 0,15 & 0,7 & 0 & 0 & 0 & 0 \\ 0 & 0,2 & 0,2 & 0,6 & 0 & 0 & 0 \\ 0 & 0 & 0,2 & 0,1 & 0,7 & 0 & 0 \\ 0 & 0 & 0,1 & 0 & 0,2 & 0,7 & 0 \\ 0 & 0,2 & 0 & 0 & 0 & 0,1 & 0,7 \\ 0,5 & 0 & 0 & 0 & 0 & 0 & 0,5 \end{Vmatrix} \quad (9)$$

The matrix ‖ πij ‖ reflects a state of the system, in which the preconditions of success of states as a degree of excellence of the project team during its operation are formed. This matrix is formed on the basis of time spent at each stage of the development and operation of the project team. Time costs are determined using internal models of forming the project team based on the competence and role-based approach.

Thus, at the first step of forming the project team members' time spent for orientation and gaining confidence are equal ($\pi_{1.1} = \pi_{1.2} = 0,5$). At the transition from the state of confidence in the state of clarifying the aim the time costs are average ($\pi_{2.3} = 0,7$), and the state of orientation is the time spent on the lower level ($\pi_{2.1} = 0,15$). The biggest time costs are at the transition from the state of clarifying the aim into the state of commitment when team members encounter the question "How are we doing it" ($\pi_{3.4} = 0,6$) and from the state of commitment into the state of the role assignment ($\pi_{4.5} = 0.7$) and at the transition of the state of the role assignment into the state of high productivity ($\pi_{5.6} = 0,7$). Time spent for the state of update and for returning to the state of orientation are equal ($\pi_{7.7} = \pi_{7.1} = 0,5$). It depends on whether the team members find motivation and new goals for future projects.

The results (Figure 3) show that at the 3rd step of the project probability p_3 ($k = 3$) is maximum, that corresponds to the stage of clarifying the aim.

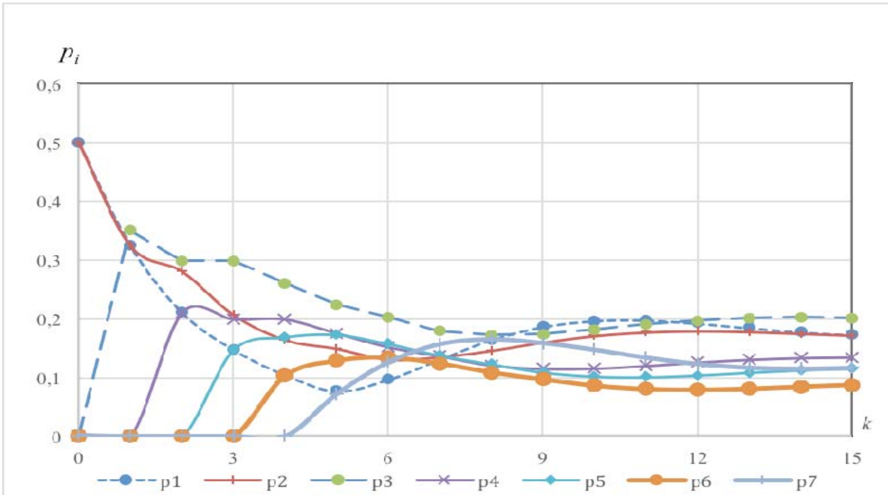

Figure 3 Changing the states of the team behavior

At the 15th step probability p_6, corresponding to the stage of high productivity is minimal and is equal to 0,09. This implies a lack of synergy and spontaneous interactivity in the operational process. The reason for this is incorrect role differentiation shown by probability p_5, which is at the 15th step is equal to 0,11. Thus, processes are unclear, performance is undisciplined and deadline omissions and conflicts are inevitable.

The results of this project are used to analyze the new distribution of the system states by means of the Markov's model. Changes of probabilities occur due to "including" in-depth knowledge [5] and adaptive learning system.

Adaptive learning is performed by using some specified level of complexity of learning material, as well as the mechanism of adaptation. In asynchronous interaction between project team members, it goes at a pace specified by chosen hypothesis and model of learning (level of competence) [1], so the current level of knowledge should be adaptively considered. This requires the use of adequate information and logical and mathematical models, algorithms (formalizing the adaptation mechanism, control) and instrumental and technological support.

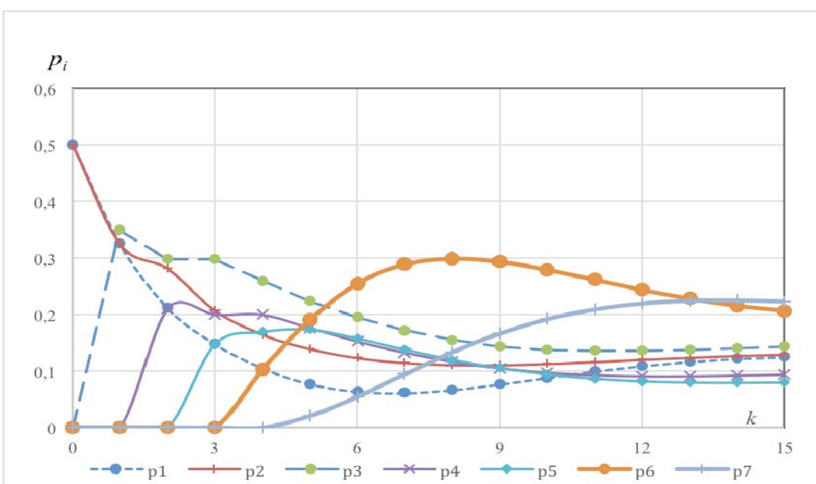

Figure 4 The change of the state probabilities due to "including" the in-depth knowledge system and adaptive learning

Applying the adaptive project system is bilateral. On the one hand, the educational system represented by the project team and teaching staff with its methods, forms, content and technologies is actively adapted to the individual characteristics of one team member. On the other hand, the team member is adapted to this system, bringing qualitative changes occurring in his physiological and social characteristics that affect the outcome of the project activities. Considering the fact that the change of indicators in the project team was expected and time costs are changing the new values of transition probabilities are determined:

$$\|\pi_{ij}\| = \begin{Vmatrix} 0,5 & 0,5 & 0 & 0 & 0 & 0 & 0 \\ 0,15 & 0,15 & 0,7 & 0 & 0 & 0 & 0 \\ 0 & 0,2 & 0,2 & 0,6 & 0 & 0 & 0 \\ 0 & 0 & 0,2 & 0,1 & 0,7 & 0 & 0 \\ 0 & 0 & 0,1 & 0 & 0,2 & 0,7 & 0 \\ 0 & 0,1 & 0 & 0 & 0 & 0,7 & 0,2 \\ 0,2 & 0 & 0 & 0 & 0 & 0 & 0,8 \end{Vmatrix} \quad (10)$$

Changing the transition probabilities leads to increase in productivity and update, reflected by probabilities p_6 and p_7 at the 15th step, which are respectively equal to 0,21 and 0,22 (Figure 4).

The main principles of the adaptive learning project team are the selection and analysis of learning indicators based on goal-setting and competence approaches, interactivity, accounting cognitive styles, motivation of transition from one level of learning to another one (increasing competence) not abruptly but flexibly changing, selecting the optimal regime of the learning process. If the project team can get this new knowledge, there is an increase in the state probabilities at different stages of the project team.

3. CONCLUSIONS

Effective management and team behavior, built on the Drexler and Sibbet's model help to reach the stage of effective teamwork when roles in the team are clearly defined; relationships are built and deepened, and therefore are not sorted out; and processes are clearly built and team members work at the development of the project at full capacity and improve the product. Thus, the change of teamwork states using the Markov's chain allows to quantify the course of project processes as a result of changes in the project team due to problems with which both each team member and the whole team will be faced at seven stages of cooperation. On the one hand, the investigation characterizes the quality and efficiency of the model. On the other hand, it can show the applicability of the model at project initiation. The model reflects the probability of states (processes) with known transition probabilities.

Improving operations and processes, which can lead to changes in transition probabilities, is the basis of improving the system. It is necessary for the effective development of the system is the use of information technologies and rational choice of the objective.

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