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ANALYSIS OF SHIP TRAFFIC OVER SUBSEA PIPELINE IN THE GDAŃSK BAY AREA

ABSTRACT

The paper discusses issues of the impact of traffic density of the vessels on the sea surface to offshore underwater pipelines. The risk includes vessel foundering, sinking, grounding, dropping and dragging anchors, trawling fishing gear. The density of merchant, offshore field support vessels and fishing vessels presented by this paper is base for build risk model for underwater infrastructures. As an example it has been analyzed ships traffic over underwater gas pipeline between platform Baltic Beta and Wladyslawowo power plant.

Keywords:
underwater gas pipelines, offshore safety, offshore risk management, offshore industry.

INTRODUCTION

The increasing demand for natural resources are the reason for the transfer process of research, exploration and extraction of hydrocarbons from shore to the underwater exploration. Due to this purpose there are created offshore oil rigs and supplies nets. With the exploitation of offshore hydrocarbons deposits it becomes necessary to build underwater infrastructure. Transport of hydrocarbons is carried out using tankers loading oil directly from the installation of platforms, FPSO-type unit, installation/mooring buoy and subsea pipelines. Offshore pipelines are divided into pipelines for the transport of oil or gas from the mining areas to the terminals on the coast and to transport hydrocarbons from deposits onshore as a transit to other onshore receiving facilities. Technological development allows laying pipelines on the ever greater depths and the intensification of exploration and extraction materials from under bottom deposits resulted in a significant increase in the amount of undersea infrastructure. China, for example, have a 3000 km undersea pipelines and in the next decade are planning to triple the length of this infrastructure. Linked to this fact it rises the problem of the safety of such structures and the safety of the marine environment at risk of failure or damage. Statistical data indicate that a significant threat to underwater pipelines is the ships traffic especially with it the risk of damage by the anchors or directly the hull hit. An important factor of damage and leakage of the pipeline is also its corrosion. The Figure 2 shows the statistics of damage to offshore sector pipelines. The data come from a database PARLOC 2001 in years 1960–2003 and concern pipelines in the North Sea. The database includes 1,567 pipelines with a total length of 24837 km. The amount and type of damage according the PARLOC 2001 database presents Figure 1.

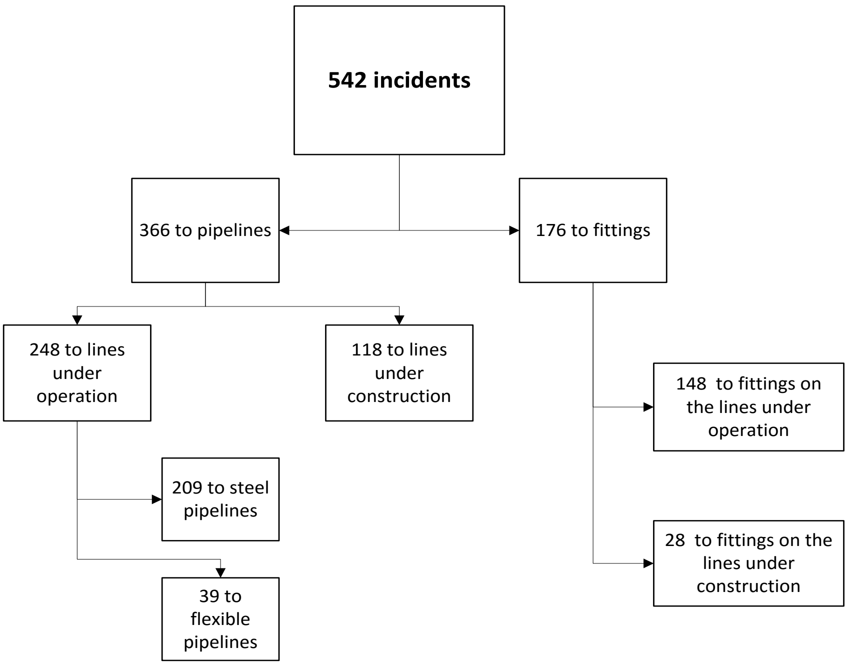

Fig. 1. Underwater pipeline incidents; data from PARLOC 2001 database

Database PARLOC 2001 groups the most common causes of damage to the: damage by anchors of vessels passing above the pipeline, hit by the ship's hull, corrosion, technical defects, defects in materials, natural hazards, structural defects, technical maintenance, human error, operational problems, others.

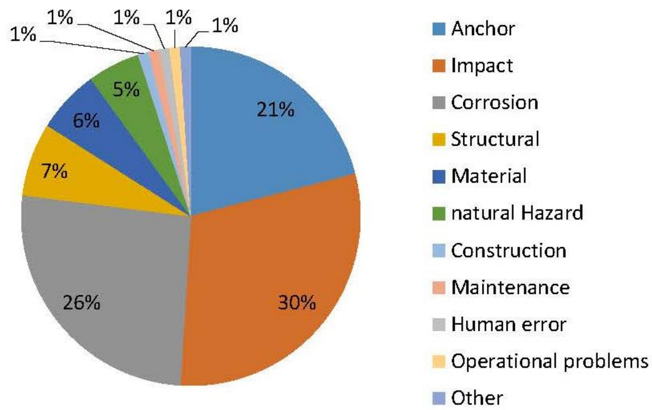

Fig. 2. Underwater pipeline damage statistic; data from PARLOC 2001 database

Risk of the offshore infrastructure is very important topic for companies operating the oil and gas fields as well for the classification societies and safety institutions which create rules and recommendations for them. They can be found for example in DNV Det Norske Veritas or HSE recommendations [DNV-RP-F111, 2010; DNV-OS-F101, 2010; DNV-RP-F107, 2010]. Moreover there are scientific researches concerning safety and risk assessment in area of the risk for underwater pipelines. Authors based the paper on some of them [Kyriakides, 2001; MacDonal, 2003].

As regards the damage factor associated with the traffic over the pipeline the most frequent damage is caused by the fishing vessel trawling the nets over the pipeline 44% and damage by ships anchors 37%. Building a risk model such causes must be taken into account. Scenarios risk assessment should take the following factors: vessels passing the pipeline, including oil rig support ships (supply vessels, floating cranes, ships, surveillance and diving vessels), merchant ships and ferries, fishing vessels. Assuming emergency situations it should be considered situations of emergency anchors dropping or dragging (important data are type and weight of anchors) and bottom trawling (network type, trawl thrust) as well as the characteristics of the pipeline: the type (steel, flexible), the depth of the basin, deep depressions in the ground, pipeline diameter, wall thickness and pipe lagging. Models of risk assessment should take into account possible consequences for the pipeline in the case of impact or anchors attaching.

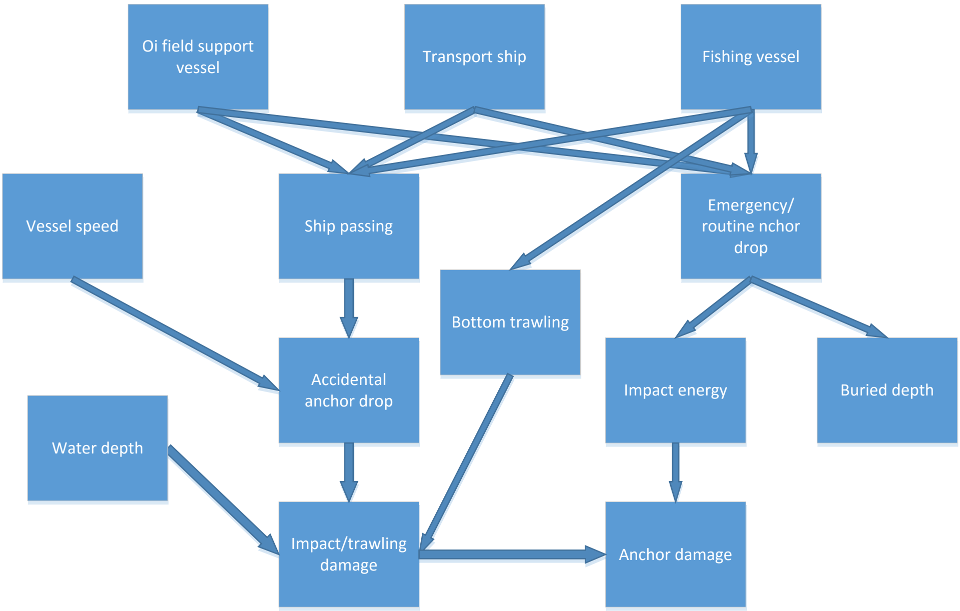

Fig. 3. Acyclic graph of anchor and trawling damage

OFFSHORE ACTIVITIES IN THE POLAND'S ECONOMIC ZONE

The exploitation of underwater resources by Polish companies takes place in Poland's economic zone. In the complex process of subsea exploitation, the extraction of oil and/or gas is one of the last stages. Starting from the development of a geological model of production sites making use of geophysical survey, the operations include the assembly and fixing of drilling and production platforms and underwater systems of pipelines and networks, seaborne transport of hydrocarbons to land, movement of drilling rigs to new locations and periodical reconstruction of existing wells. Given below are upstream activities related to the oil and gas production and operation and maintenance of existing wells located in the Polish economic zone:

– exploration is performed by:
  - seismic reflection survey vessels 'Polar Duke' and 'St. Barbara' that carry out 3D seismic survey within the licensed area of exploration in fields B21 and B16 (Fig. 4), and drilling of exploration holes,

  - drilling holes for geophysical survey and measurements, executed by Petrobaltic, Lotos Petrobaltic rigs;
- production performed by various types of rigs:
  - jackup — stationary production rigs,
  - jackup — mobile drilling rigs,
  - jacket — stationary unmanned production rigs;
- exploration and exploitation wells are established in licensed areas; exploitation wells are used for oil and gas extraction as well as injection of deposit water and seawater filtered to optimize the production;
- transfer of gas via an underwater pipeline to Wladyslawowo;
- transshipment from a single buoy mooring (SBM) situated near the Baltic Beta rig and carriage of oil by the mt IKARUS III to Gdańsk;
- transshipment from a single buoy mooring (SBM) situated near the Lotos Petrobaltic rig and carriage of oil by the mt Apatyth to Gdańsk;
- continuous supplies to the rigs by offshore vessels and supervision provided by standby vessels; at present, the vessels employed for the purpose are the tugs ‘Agath’, ‘Bazalt’ and ‘Kambr’ and support ships ‘Aphrodite I’ and ‘Sea Force’;
- jackup rigs towage to new drilling locations;
- submarine work: diving and maintenance, use of remotely operated vehicles (ROV).

Exploration and production in the Polish sea territory cover about 29.000 km^2. LOTOS Petrobaltic licences for the search and identification of hydrocarbon deposits comprise eight fields with a total area of 8.200 km^2 in the eastern part of the Polish offshore region [Dzikowski, Ślączka, 2014].

The capital group LOTOS Petrobaltic also has four licences for the extraction of oil and gas from fields B3, B4, B6 and B8. At present, crude oil is produced in field B3 and B8. The map below shows areas with licences for exploration and production (Fig. 4).

The system of gas transfer from Baltic Beta to Wladyslawowo consists of the following items:

1. The gas compression station on an oil rig Baltic Beta.
2. Submarine transmission pipeline with a length of 82 km and a diameter of 115 mm. The pipeline has been constructed according to the technology of Precision Tube Technology of Houston company. Steel pipes are insulated with poliethylan.

3. The station separation, gas storage and preparation of fuel for the power plant with a capacity of 120 000 Nm3/day.
4. Wladyslawowo power plant with 2 gas turbines and two heat recovery boilers of total electric power approx. 12 MWe and heat approx. 18 MWt, 3 peak boilers for gas and oil with a total capacity of 15 MW.
5. District heating net from Wladyslawowo with a length of approx. 9 km.

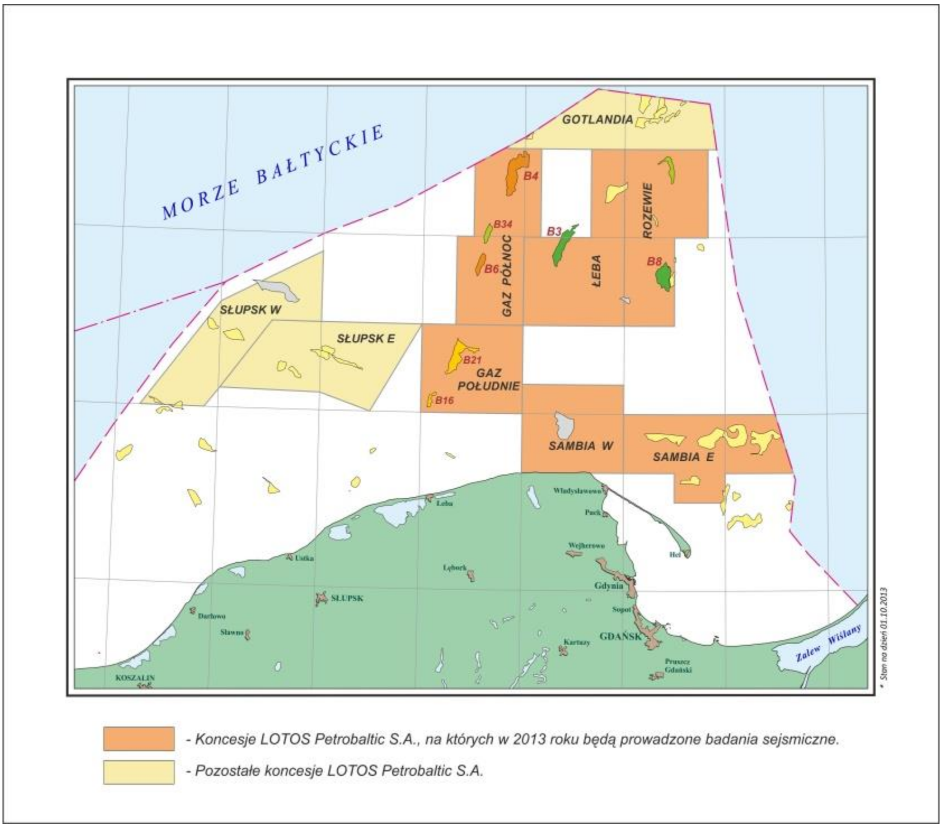

Fig. 4. Licenced areas of oil/gas production within the southern Baltic (in brown - area of seismic investigation) [http://www.lotos.pl/ (access 17.09.2016)]

Underwater pipeline and the underwater infrastructure in Baltic Beta safety zone is shown in the Figure 5.

Pipeline characteristic:

- material of pipe — steel X65C,
- pipe tension parameters: Re = 455 Mpa, Rm = 540 Mpa,

- protection — 3 layers: Valspar epoxide material, Dupont epoxide polymer, polyethylene material,
- internal diameter 114,3 mm,
- external diameter 101,6 mm,
- first transmission of natural gas was in August 2002
- first heating season using natural gas started Autumn 2003 in Wladyslawowo.

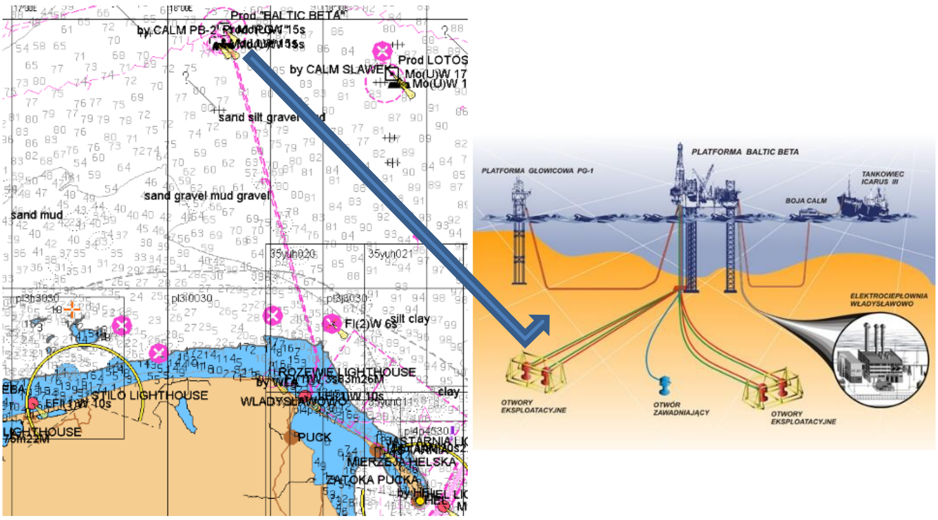

Fig. 5. Underwater pipeline from Baltic Beta oil rig to Wladyslawowo power plant and scheme of the underwater infrastructure [http://www.lotos.pl/, ENC chart (access 17.09.2016)]

CASE STUDY

Prior to commencing the risk assessment to the underwater pipelines is to indicate judge criteria, weather risk is intolerable, acceptably low or broadly tolerable. The single dominant risk for damage of underwater gas line is large underwater gas leak, leading to the possibility of very significant gas cloud near sea surface, which if ignited will produce a large gas fire. As a danger arising for people is low due to distance to land but there is economic loss that would be suffered if the pipeline would be severely damaged and out of service. The principal risk contribution can be divided in to groups: passive and active. Passive are: fault(material, welding, etc.), corrosion, erosion, land-slide and active: anchor drop, anchor drag, sinking/ foundering vessel, grounding, trawling by fishing vessel. Anchor drop damage to the pipeline can be effective from direct hit by the anchor onto the pipe with sufficient kinetic energy to damage pipeline. Model of pipeline damage should consider frequency of passing and characteristic of anchors. Anchor drag is considered to more likely to the specific pipelines especially within near shore area. The frequency of passing, type of anchor and soil condition should be calculated in damage model. In general anchor hold 2,5 times its weight. For example anchor weight 10 tons has holing capacity 20 to 50 tonnes.

In the paper authors tried to analysis the ship traffic over the pipeline between Wladyslawowo and Baltic Beta platform to find out density of traffic over pipeline and establish risk areas for pipeline. The procedure to estimating the probability of anchor or trawl damage P^a can be described by equitation:

$$P^a = \sum_{i=1}^{n} N_i \, P_a^i. \tag{1}$$

In the equitation $i(1, \ldots, n)$ means the i^{th} type of the ship. N_i is the frequency of the i^{th} type of the ships passing by per year. P_a^i is probability of the anchor or trawling damage once an *i*-type ship passing through. It is considered oil rigs support ships, transport ships and fishing vessels. The probability of the trawling damage P^t is described by equitation:

$$P^t = N_{fv} P_{fv}^t \tag{2}$$

Where N_{fv} is the frequency of fishing vessel running through the offshore pipeline per year, and P_{fv}^t expresses the probability of trawling damage by trawling damage by one fishing vessel. Traffic density is shown in the Figure 6. Over the traffic density pattern there are marked routs of oil rig support vessels and oil tankers transferring oil to Gdańsk port.

First step to build the risk and damage model of underwater pipeline is to analyze traffic over the pipeline. On the base of the known traffic there is possible to collect data about anchor types an weights of ships mostly passing over pipeline areas and fishing gear of the fishing vessels passing over the pipeline. Ship anchoring procedures can be divided into two scenarios:

1. Routine anchorage when the process of anchoring is early prepared and planned. This one is not thought to be risky.

2. Extraordinary dropping the anchor in case of emergency for example: engine failure, bad weather, ship collision, loss of control, technical problems. This scenarios is dangerous for pipeline and can be critical.

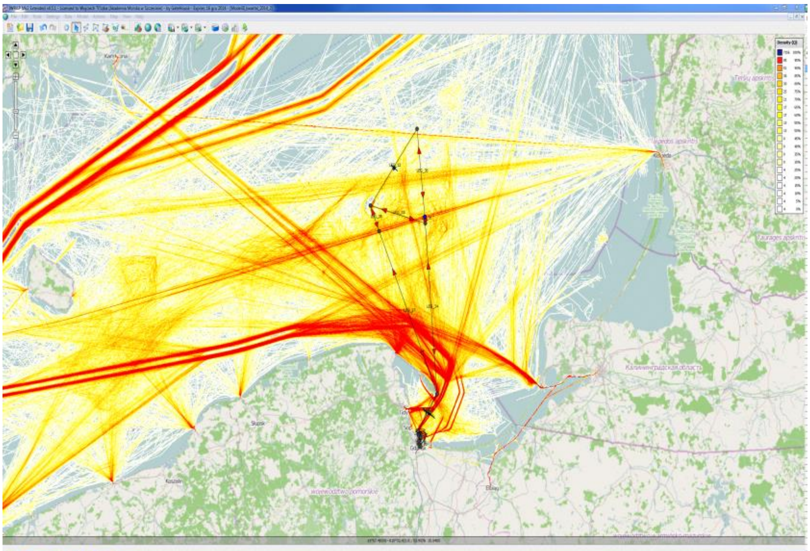

Fig. 6. Traffic pattern with marked routes of offshore support vessels

In the paper the analyzed pipeline is divided into three zones. First one is the shore zone near entrance to the port. Second one is open sea zone crossed by shipping lanes and passed by trawling fishing boats. Third one is offshore platform safety zone where there is only traffic of offshore support vessels, oil tankers collecting oil and mostly moored to the single mooring buoy, geophysics vessels, vessels accidentally entering the area. In this zone there are very strictly safety procedures for approaching ships and this one is not covered by this paper (Fig. 7). In the case of oil rig Baltic Beta that is 2 Nm area.

Three outcomes denote that subsea pipeline may be hit or damaged by dragged anchor. There are:

- vessel characteristic (identification number, ship particulars, movement tracks);
- anchor arrangement parameters (anchor type, class and mass, chain weight and type);
- pipeline characteristic (positions of the pipeline systems, seabed profile, material type).

To build the risk model essential is to consider marine traffic volume and vessel population over pipeline. That aspect is analyzed in this paper. It is important to realize that the number of emergency situation is dependent on the number of the ship and fishing vessels passing.

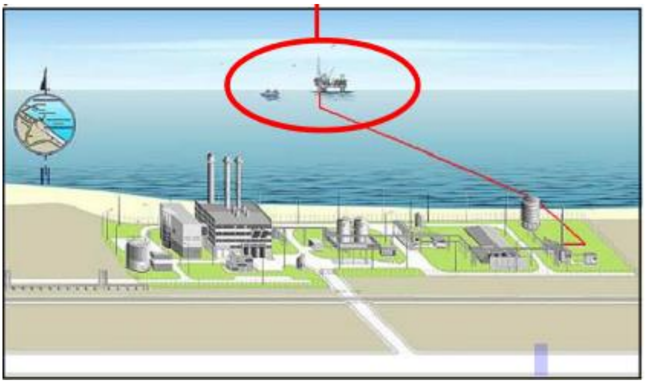

Fig. 7. Excluded zone in this paper [http://www.lotos.pl/ (access 17.09.2016)]

In the paper the study of ships crossing over a submarine pipeline distribution was carried out. The study was conducted on the following sections of the pipeline leading from Baltic Beta oil rig to Wladyslawowo:

– I section (55°27,0'N 018°12,2'E and 54°51,0'N 018°29,0'E);
– II section (54°51,0'N 018°29,0'E and 54°48,9'N 018°27,3'E).

The research area and traffic distribution over the submarine pipeline has been marked in red in the Figure 8.

In order to determine the frequency and to indicate the places where the ships pass over the submarine pipeline the AIS data from two summer months (June and July of 2011) were used. In those month's that was highest vessel traffic density. In the diagram 9 below the ships passing distribution is presented depending on the latitude of the exact place where ships were crossing over the pipeline. The pipeline is divided into 13 sections (every 3 minutes of latitude) or approximately every 3 nautical miles. In designated section in the period from June to July 2011 the pipeline was passed by 2,334 ships nearly 39 ships a day.

The diagram in the Figure 9 shows that the largest number of vessels cross over the pipeline between 54°54,0'N and 54°57,0'N, where in the period of two months 711 ships were observed (based on AIS data) it is over 30% of all ships passing the designated area. This means that the daily traffic is about 12 vessels.

Then, the further to the south, the smaller number of vessels is observed in each section up to the penultimate section between 55°21,0'N and 55°24,0'N where increased number of vessels (235 it is about 10% of all) is observed.

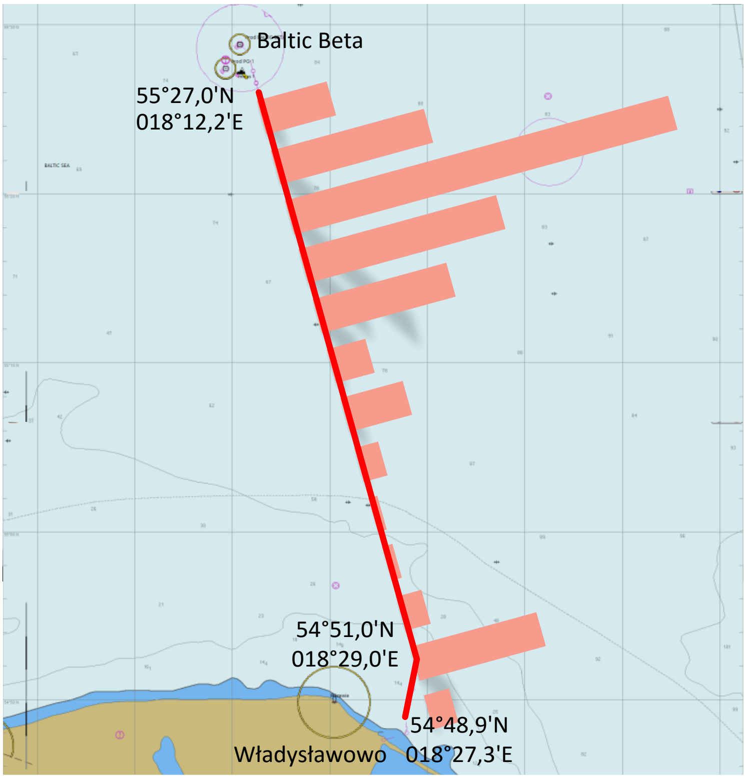

Fig. 8. Underwater pipeline leading from Baltic Beta oil rig to port of Wladyslawowo with distribution of ships passing

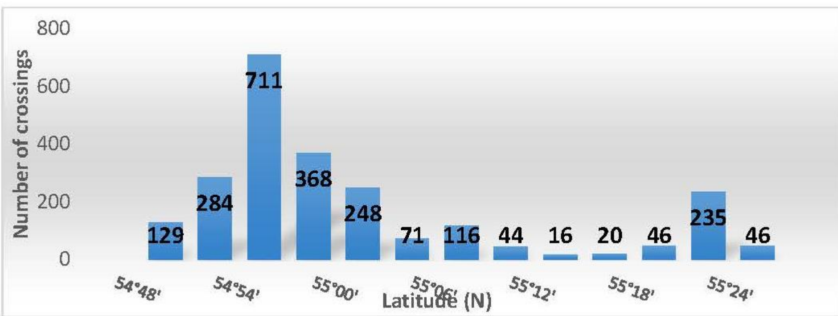

Fig. 9. Ships passing distribution over the underwater pipeline

The diagram in the Figure 10 shows the length of vessels passing over selected for the study sections of the pipeline. The vast majority of them is located in the ranges of 60 m to 120 m and from 120 m to 180 m. As depicted in the diagram there are also vessels of length exceeding 240 m observed passing the pipeline. The draft of vessels in the study area are presented on the Figure 11. It should be noticed that there are 23 ships or about 1% of all vessels which draft exceeds the 12 m.

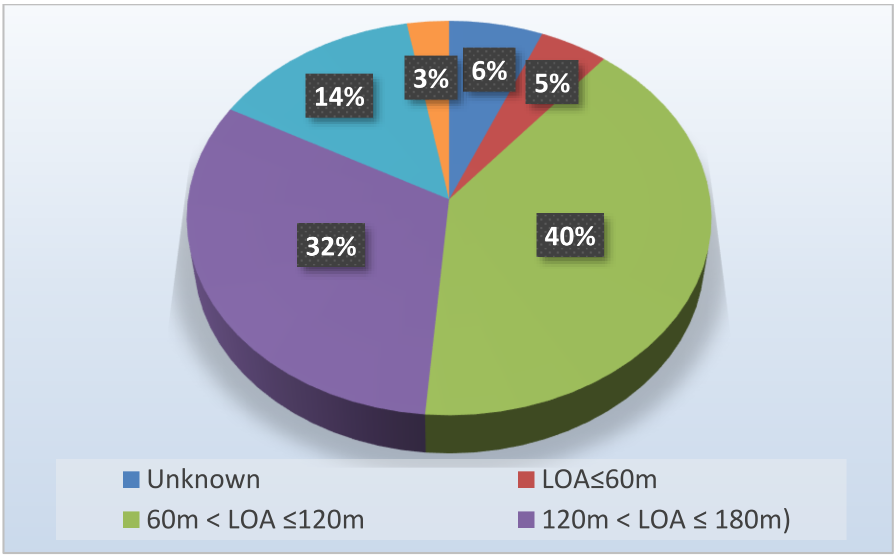

Fig. 10. The Length over all (LOA) of vessels passing over pipeline

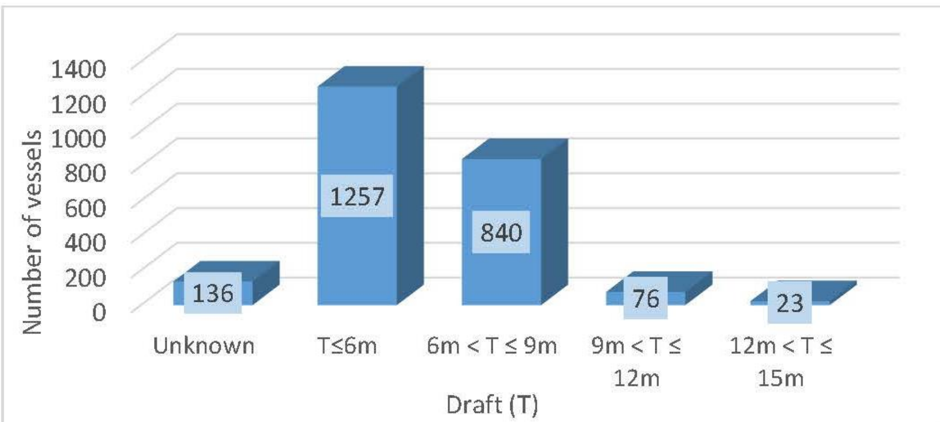

Fig. 11. The draft of vessels passing over the pipeline

CONCLUSIONS

The paper presents a method of the live traffic analysis to obtain data necessary to conduct under water risk assessment. AIS data gives data to analyze ship traffic volume passing over underwater pipelines and infrastructure. AIS data gives not full information about fishing vessels traffic. Fishing boats under 12 meters long are not obliged to carry AIS system. That is necessity to obtain data about fishing vessel traffic from other systems for example VMS data. Traffic patterns gives possibility to find most endangered parts of underwater pipeline and infrastructure. Characteristic of equipment of the ships and fishing boats passing over the pipeline should be obtained from database like vesselregister.dnvgl.com, www.eagle.org, etc. The benefits of composed database of ships and fishing boat traffic can be used for offshore risk analyses, offshore wind farms situation, collision risk management, traffic routes management.

REFERENCES

[1] DNV-RP-F111, Interference between Trawl Gear and Pipelines, 2010.

[2] DNV-OS-F101, Submarine Pipeline Systems, 2010.

[3] DNV-RP-F107, Risk Assessment of Pipeline Protection, October 2010.

[4] Dzikowski R., Ślączka W., Analysis of IWRAP mk2 application for oil and gas operations in the area of the Baltic Sea in view of fishing vessel traffic, 'Scientific Journals of The Maritime University of Szczecin', 2014, Vol. 40, pp. 58–66.

[5] HSE, Guidelines for Pipeline Operators on Pipeline Anchor Hazards, 2009.

[6] Kyriakides S., Mechanics of Offshore Pipelines, The University of Texas at Austin and Edmundo Corona University of Notre Dame, 2007.

[7] MacDonal M., 'PARLOC 2001' The update of loss of containment data for offshore pipeline, Prepared for The Health and Safety Executive, The UK Offshore Operators Association and The Institute of Petroleum, 12 June 2003.

[8] Yuan Zhuang, Yang Li Wei Su, Influence of Anchoring on Burial depth of submarine pipelines, Myung-Il Roh, Seoul National University, Republic of Korea, 2016.

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STRESZCZENIE

W artykule omówiono problematykę wpływu gęstości ruchu statków na bezpieczeństwo rurociągu podwodnego. Zagrożenia takiego rurociągu obejmują między innymi uderzenie, zaczepienie lub uszkodzenie bezpośrednio przez kadłub statku, jego kotwice, a także zaczepienie zestawem trałowym statku rybackiego. Analiza gęstości ruchu nad rurociągiem pozwala na budowę modelu ryzyka rurociągów osadzonych w dnie morskim oraz modelu zagrożenia dla rozbudowanej infrastruktury podwodnej. Jako poligon badawczy przyjęto rurociąg gazowy łączący platformę Baltic Beta i elektrownię Władysławowo.