Problems of towing of damaged tankers

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Abstract
Tanker casualties that happen from time to time in the world cause serious damage to environment with disastrous effects. In particular, casualties of tankers “Prestige”, “Erika” and “Nakhodka” where ships were seriously damaged, broken in the middle or separated into two parts showed that salvage operations in many cases were not effective. Such casualty in the Baltic Sea, that is closed area, may lead to the total destruction of the environment. The paper describes a proposed system of preventing marine environment pollution from damaged tankers. Problems related to towing of damaged tankers to the safe harbour or area, that consist an important element of the system, are discussed in more detail with reference to model tests of towing of damaged tanker performed at Ilawa Training and Research Centre for Ship Manoeuvrability.

Introduction
From time to time the public opinion is shocked by the information that somewhere in the world there was serious shipping accident where damaged large crude oil tanker caused disastrous pollution of the sea environment. In consequence, hundreds kilometers of the seaside were polluted and were of no use for tourism, recreation and for fishery, sea life was damaged for a long time and resulting cost of recovery was counted in hundreds of millions of US dollars. Those accidents happen in spite of enhanced international safety rules adopted regarding construction of tankers during the last period, where double hull, segregated ballasts, duplicated rudder gear amongst other measures are required. Avoiding disastrous consequences of such accidents requires immediate localization of the casualty, securing the damage ship as far possible, towing it to the safe place where oil spill could be contained and removed. Rescue and cleaning action has to be quick and effectively performed.

Important oil spills and their consequences
The most serious tanker casualties that happened in years 1967–2008 are shown in the table 1 (from [1]). In the last column amount of oil that went to the sea is shown, and largest oil spills polluting the coastline are marked by star. In older times when
the size of tankers was generally rather small, casualties, if they happen, did not cause large pollution because of small amount of oil spilled. The rapid increase of the amount of oil transport and of the tankers size in the sixties of the last century has changed the situation.

Table 1. Most serious tanker casualties and oil spills from tankers in years 1967–2007
Tabela 1. Najpoważniejsze awarie zbiornikowców i wylewy ropy naftowej w latach 1967–2007

<table>
<thead>
<tr>
<th>Month / Year</th>
<th>Ship’s name</th>
<th>Place</th>
<th>Oil spill / sunk (t × 10^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/1967</td>
<td>Torrey Canyon*</td>
<td>Scilly Isles</td>
<td>119 000</td>
</tr>
<tr>
<td>03/1971</td>
<td>Wafra</td>
<td>South Africa</td>
<td>65 000</td>
</tr>
<tr>
<td>08/1974</td>
<td>Metula</td>
<td>Magellan Strait</td>
<td>50 000</td>
</tr>
<tr>
<td>01/1975</td>
<td>Jacob Maersk</td>
<td>Oporto, Portugal</td>
<td>88 000</td>
</tr>
<tr>
<td>05/1976</td>
<td>Uruela</td>
<td>Galicia, Spain</td>
<td>101 000</td>
</tr>
<tr>
<td>01/1977</td>
<td>Nakhdoka*</td>
<td>Japan Sea</td>
<td>6 000</td>
</tr>
<tr>
<td>02/1977</td>
<td>Havaian Patriot</td>
<td>Hawaii</td>
<td>95 000</td>
</tr>
<tr>
<td>03/1978</td>
<td>Amoco Cadiz*</td>
<td>Brittany, France</td>
<td>223 000</td>
</tr>
<tr>
<td>11/1979</td>
<td>Independent*</td>
<td>Bosphorus</td>
<td>95 000</td>
</tr>
<tr>
<td>07/1979</td>
<td>Atlantic Empress*</td>
<td>Tobago, West Indies</td>
<td>287 000</td>
</tr>
<tr>
<td>02/1980</td>
<td>Irenes Serenade</td>
<td>Navarino Bay</td>
<td>100 000</td>
</tr>
<tr>
<td>01/1983</td>
<td>Assimi</td>
<td>Oman</td>
<td>53 000</td>
</tr>
<tr>
<td>08/1983</td>
<td>Castillo de Bellveder*</td>
<td>South Africa</td>
<td>252 000</td>
</tr>
<tr>
<td>11/1988</td>
<td>Odyssey</td>
<td>Nova Scotia,</td>
<td>132 000</td>
</tr>
<tr>
<td>03/1989</td>
<td>Exxon Valdez*</td>
<td>Alaska</td>
<td>37 000</td>
</tr>
<tr>
<td>12/1989</td>
<td>Khark 5</td>
<td>Morocco</td>
<td>80 000</td>
</tr>
<tr>
<td>04/1991</td>
<td>Haven</td>
<td>Genoa, Italy</td>
<td>144 000</td>
</tr>
<tr>
<td>05/1991</td>
<td>ABT Summer</td>
<td>Angola</td>
<td>260 000</td>
</tr>
<tr>
<td>04/1992</td>
<td>Katina</td>
<td>Mozambique</td>
<td>72 000</td>
</tr>
<tr>
<td>12/1992</td>
<td>Aegean Sea</td>
<td>Galicia, Spain</td>
<td>74 000</td>
</tr>
<tr>
<td>01/1993</td>
<td>Braer</td>
<td>Shetlands</td>
<td>85 000</td>
</tr>
<tr>
<td>02/1996</td>
<td>Sea Empress*</td>
<td>Milford Haven</td>
<td>72 000</td>
</tr>
<tr>
<td>12/1999</td>
<td>Erika*</td>
<td>Brittany, France</td>
<td>20 000</td>
</tr>
<tr>
<td>11/2002</td>
<td>Prestige*</td>
<td>Galicia, Spain</td>
<td>76 000</td>
</tr>
<tr>
<td>08/2003</td>
<td>Tasman Spirit</td>
<td>Karachi</td>
<td>28 000</td>
</tr>
<tr>
<td>12/2007</td>
<td>Hebei Spirit</td>
<td>South Korea</td>
<td>10 500</td>
</tr>
</tbody>
</table>

The first serious tanker casualty that happened in European waters was in 1967 when the supertanker “Torrey Canyon”, because of the master fault, hit the Seven Stone rocks near the Scilly Island. The hull of the tanker was ruptured and spilled oil caused the most serious ecological disaster. Several other serious tanker casualties happened in years 1967–1977, many of them close to the coast of America that stirred public opinion and maritime authorities and as a result extraordinary conference was organized by the International Maritime Organization (IMO) in 1978 and Protocol SOLAS and MARPOL Conventions was adopted that included important amendments to those conventions related to tanker safety [2]. This conference almost coincided with the most serious disaster of the tanker “Amoco Cadiz” in 1978 close to shores of Normandy that was caused by rudder gear failure. Disabled ship drifted towards the rocks where the hull was eventually split into two parts and more than 200 000 tons of oil transported spilled into the sea.

More recently, in November 2002 in Greek owned tanker “Prestige” one of the tanks started leaking due to hull damage in Atlantic Ocean close to Portugal. Because all ports refuse to allow the leaking tanker to enter, the master was forced to sail farther from the shore. Attempts to tow, the disabled ship failed and during the stormy weather the ship was broken into two parts as shown in figure 1, that ultimately separated and finally foun-dered. The spilled oil drifting towards the Spanish coast caused the worst disaster in the history of Spain. The consequences of such large oil spills are disastrous for the sea life (birds, animals and fish), for the economy (fishery, tourism, recreation) and cleaning operations costs usually many millions euro.

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Fig. 1. Tanker “Prestige” broken down drifting in Atlantic Ocean
Rys. 1. Zbiornikowiec „Prestige” przełamanany, dryfujący na Atlantyku

Casualties of the Russian tanker “Nakhdoka” in 1997 that was broken into two parts in Japan sea, of the tanker “Erika” in 1999 that was also broken into two parts near Brest, and in particular of the tanker “Prestige” where attempts to tow the disabled ship failed drew attention to the problems of towing disabled ships.

System of preventing marine environment pollution from damaged tankers

Understanding that such disasters, in spite of whatever prohibitive measures are taken, are unavoidable, people realized that it would be necessary to develop a system to prevent or mitigate consequences caused by spilled oil, if such casualty
happens. This was done for the first time after the “Nakhodka” disaster, where in Japan important project of this type was installed under the leadership of professor Hara. This was reported in several places, (e.g. [3, 4]). Attempts to develop certain tools designed to help the salvage organization to deal with the consequences of similar disasters were undertaken also after the “Erica” and “Prestige” disasters [5].

Baltic Sea is a closed sea particularly vulnerable to pollution. If disaster of a large tanker, such as described above, happens in the Baltic, the results would be catastrophic to the countries surrounding Baltic Sea. In the extreme case, the whole life in the Baltic might be destroyed and the beaches made unusable for the long time. Fortunately, such disaster did not happened yet, but the risk that it may happen in future is rather high. Some indication what may happen was shown in December 2009, when the bunker ship “Romanka” lost manoeuvrability, drifted towards the Latvian coast and grounded. The ship was without cargo and on the sandy beach hull was not ruptured. Fortunately, nothing serious did happen [6].

In the Baltic Sea 55 000 ships pass the Danish Strait every year, and about 6000 of them are large or medium size tankers carrying dangerous goods; more than 50 ferry routes cross the Baltic Sea. Collision and grounding may easily happen. Therefore, it is extremely important to assess risk of such a situation and appropriate salvage action has to be prepared.

The attempt to mitigate consequences of such disaster materialized in the proposal to develop a system for preventing disastrous consequences in case of tanker casualty in the Baltic Sea [7]. Such system developed in Japan was the result of 5 years project installed after “Nakhodka” disaster and was named Optimum Towing Support System (OTSS) [4]. Unfortunately, only short publications that include description of the system and some results of the model test of damaged tankers are available, and access to the system that is owned by Japanese authorities is not possible (see references above). Moreover, the system is geared to the local conditions in Japan and model tests comprise damage cases that do not include cases that happened in “Prestige” or “Erika” casualties.

The system proposed (EPM System) should be for use in the Baltic, therefore should be tailored to local conditions. The system should make use of the Japanese experience, but will not necessarily be modeled in the same way. The block diagram of the proposed system is shown in figure 2. In order to

Fig. 2. Block diagram of the EPS system
Rys. 2. Schemat blokowy systemu EPS
To accomplish aims of the EPM system, the following tasks have to be undertaken:

Task 1: Identification of the condition and important parameters of the disabled ship.

Task 2: Identification and prediction of the hydro-meteorological condition in the area of casualty.

Task 3: Prediction of the path of drifting damaged vessel.

Task 4: Developing of the optimum towing system of the damaged vessel to the safe place.

Task 5: Developing optimum system of containment of the pollution and removal spilled oil.

Task 6: Developing user friendly fast computer code for the use of salvage organization.

**Research project on prevention of oil pollution from damaged tankers**

Bearing in mind the possibility of a large tanker being damaged because of grounding or collision in the Baltic Sea, the programme of research was installed in the Foundation for Safety of Navigation and Environment Protection with the aim to develop the system mentioned above aimed at prevention of oil pollution from damaged tankers. Part of this programme constituting important element of the system was already completed. The aim of this part was prediction of drift of a damaged tanker under the influence of wind, waves and current allowing fast intervention of the salvage ships. The results of this part were already reported [8].

The other part of the project, now under consideration, is aimed at estimation of forces required to tow the damaged tanker to the safe place where the oil spill may be contained and ultimately removed to recommend optimum towing arrangement. It is necessary to estimate forces required for towing which in turn affect the choice of tugs (necessary to do this work) and provide recommendations regarding the technique of towing. This part is almost completed and is based on model tests of towing of the model of disabled tanker in different conditions of damage. Large model of damaged ship was used for this purpose.

**Towing tests of the disabled tanker**

Within the scope of the project model tests using large model of a tanker in different damage conditions were arranged on the lake in the Research and Training Centre for Ship Manoeuvrability in Iława in order to study the behaviour of damaged tanker when towed and to develop computer code for predicting forces required for towing. Those tests are unique, because no such tests were performed anywhere yet. As a sample ship for model tests tanker of the common size met in the Baltic Sea was chosen. This was the same tanker as used for tests within the first part of the programme of research [8]. The dimensions of the chosen ship are shown in the table 2, together with dimensions of the large model used in experiments on the lake. Figure 3 shows conditions of the damage tanker that were used in model tests.

![Fig. 3. Conditions of the damaged tanker tested](image-url)
Problems of towing of damaged tankers

As the towing ship model of the large tanker “Blue Lady”, normally used for training sea pilot and ship masters was used. Large displacement of this model caused that effect of the towing ship (or tug) on the behavior of the towed ship was negligible. During tests towing force was measured, as well as velocities and paths of both ships. Also wind velocity was measured, although all tests were performed in calm weather with almost no wind in order to exclude the wind and waves effects on towing force. Those effects will be added to calm weather towing force by calculation.

Table 2. Dimensions of the sample ship and its models

<table>
<thead>
<tr>
<th>Scale</th>
<th>SHIP [m]</th>
<th>MODEL 1 [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA</td>
<td>324.0</td>
<td>7.89</td>
</tr>
<tr>
<td>B</td>
<td>54.9</td>
<td>1.34</td>
</tr>
<tr>
<td>H</td>
<td>32.25</td>
<td>0.785</td>
</tr>
<tr>
<td>T1</td>
<td>15.50</td>
<td>0.377</td>
</tr>
<tr>
<td>T2</td>
<td>21.50</td>
<td>0.523</td>
</tr>
</tbody>
</table>

During tests three lengths of towing line were used, corresponding to 500, 750 and 860 m. Tests were performed at different towing speeds.

Programme of tests of towing disabled tanker in four different conditions of damage has been already completed. Figures 4 and 5 show examples of towing arrangement.

Ocean rescuetowing

In rescue towing as rule damaged ship is not controlled and there usually are no crew members. This is usually posing serious problems in bringing the towing hawser that is rather heavy (2–3 tons) onboard and fixing it. These problems are, however, not discussed here.

When the non controlled ship is towed, usually yawing motion around the straight course occurs. Yawing motion is connected with dynamic instability of the towed ship and is difficult to avoid. An example of the trajectory of the towed vessel is shown in figure 6.

Fig. 4. Towing of the model of damaged tanker (condition 3)

Rys. 4. Holowanie modelu uszkodzonego zbiornikowca (stan 3)

Fig. 5. Towing of the model of damaged tanker (condition 4)

Rys. 5. Holowanie modelu uszkodzonego zbiornikowca (stan 4)

Fig. 6. Recorded trajectories of towed ship and tug [9]

Rys. 6. Zapisane trajektorie statku oraz holownika [9]

Yawing causes reduction of speed of towing, increases the danger of breaking of towing line because of overloading and possible lost of tow. Yawing phenomenon was studied by several authors (e.g [10, 11]) and in general, it was concluded that this phenomenon is very difficult to avoid when towing conventional ships or towing objects unless special additional arrangement in form of fitting fins or skegs or drag anchors are fitted, which cannot be done with rescue towing. Yawing, in general, depends on the inherent dynamic stability of the tow and on the length of the towing line. Generally, the longer towing line, the smaller amplitude of yawing. This relation is shown in figure 7 derived from calculations (after [11]). This, however, was calculated taking as an example of towed ship a naval ship that was inherently stable on straight course when towed. Most ships when towed, reveal larger or smaller amplitude of yawing. Tests with towed gas carrier model confirmed this effect [12].
The negative result of yawing motion of the tow is jerking of the tow line. When the tug is pulling even at constant speed, yawing of the tow is causing that the pulling force is not constant, but is changing in time. When the yaw angle of the tow is at its extreme, then the tow accelerates the towing line became slack and the jerking occurs when the tow rope is again taut. Therefore, on the steady or quasi-static pulling force jerking force is overlapping as shown in figure 8 (after [13]). In this diagram, additional time varying components of tension caused by waves are also shown.

The extreme time varying tensions are compensated by the construction of the towing hawser that, when wire rope is used, always include highly elastic part, as well as by the towing winch that automatically releases rope when the tension increases.
over certain value, but even so, the towing hawser diameter should be calculated taking into account additional jerking tensions. The behaviour of the towing hawser is very complex and several authors attempted to investigate it and to develop computer codes able to calculate extreme tensions (e.g. [14, 15]), but this subject it out of the scope of this paper. On rough recommendation as used by the U.S. Navy is to use safety factor 1.5 [13].

**Some results of the towing experiments**

Figure 9 (from [16]) shows partial results of the experiments of towing damaged ship. Towing forces measured are shown for three different lengths of towing line for the model in condition 3 (model broken in the middle). It may be noticed, that the forces re-calculated for full scale ship are extremely large, therefore, towing speed should be rather small, perhaps no more than 3–3.5 knots. Large scatter of measured points is due to jerking forces caused by yawing motion.

**Conclusions**

The tests with towing of damaged tanker in different conditions of damage did show that this operation may be very difficult and the forces required to tow such a ship might in certain situations be extremely large. This will require employment of powerful tugs having very large bollard pull. Usually there will be also difficulties with bringing heavy towing hawser onboard of the damaged vessel. In order to avoid disastrous pollution of the sea, a system of preventing marine environment from spilling oil from damaged tankers should be developed as proposed. This is especially important for the Baltic Sea.

**Acknowledgement**

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**References**


**Other**