The paper presents detailed results of a comprehensive analysis of recorded AFRAMAX tanker incidents and accidents, which occurred in the period between 1978 and 2003. The analysis consists of a thorough review of incident/accident information and identification of the significant trends such as variation of accident rates per shipyear for all accidents as well as for each major accident category (collision, contact, grounding, non-accidental structural failure, fire, and explosion); the environmental and operational conditions at the time of incidents/accidents (en-route, loading/unloading, manoeuvring, at port, etc); and the severity of accidents in terms of loss of lives/injuries, environmental pollution and loss of property (minor, major repairs or total loss). These trends were also analysed with respect to the impact of ship design (double hull and non-double hull), of human and a variety of other factors.

The analysis results show a clear decline in the accident rates per shipyear for the particular period. Although similar reduction in accident rates leading to oil pollution was observed, the spilled pollution rates remained almost constant. Also, the analysis indicated that the spilled pollution index for accidents involving double hull tankers was significantly lower compared to the index for non-double hull tankers.

1. INTRODUCTION

The European Commission provided funding for a 3-year project entitled “Pollution Prevention and Control – Safe Transportation of Hazardous Goods by Tankers” (POP&C) under Framework Programme 6 (FP6), which started in January 2004 [1].

The main aim of the POP&C project is to develop a framework and first-principles tools for a methodological assessment of risk, which could then form a rational basis for making decisions pertaining to design, operation and regulation of oil tankers. Such rational assessment methodology can be used to make more informed decisions, which will in turn contribute to reducing the likelihood and severity of future oil spills.

The first step of a risk assessment methodology is to carry out a Hazard Identification and Ranking (HAZID) study. In the context of the POP&C project, the main purpose of this exercise was to identify main hazards that lead to a vessel’s loss of watertight integrity and consequently cause pollution and environmental damage. Such a hazard analysis and ranking study can conveniently be carried out by analysing the incident/accident performance of a representative sector of the industry. Therefore, in order to demonstrate the methodology which is being developed, the POP&C project selected to analyse the AFRAMAX class of tankers. Reasons for this selection were the relatively large market segment of the AFRAMAX tankers, past spectacular catastrophic tanker accidents involving AFRAMAX tankers and relatively high number of single hull AFRAMAX tankers which are currently operational and expected to continue operating until they reach the recently amended (accelerated) phase-out date [2].

For this purpose, a rational database of AFRAMAX tankers was set up to enable the full exploitation of the raw incident/accident data which was commercially available from Lloyd’s Marine Information Services Ltd (LMIS). Much of the incident/accident information contained in the LMIS database is in textual format and it is consequently difficult to extract and analyse this information systematically. Therefore, the textual information presented in the LMIS database had to be re-analysed by a team of POP&C project partners before it could be introduced in the newly developed database. The ultimate purpose of this new database was to facilitate the populating of the POP&C Risk Contribution Fault Trees (FTs) and Event Trees (ETs) of the identified six accident categories which can potentially lead to loss of watertight integrity of a tanker’s hull. The six accident categories are: Collision, Contact, Grounding, Non-Accidental Structural Failure, Fire, and Explosion.

Based on ship’s operating condition at the time of incident/accident and based on the event location, it is evident that the causes of some incidents/accidents are strongly related to operational procedures and practices and consequently they reflect human error.

2. POP&C DATABASE

2.1 SOURCE OF INCIDENT/ACCIDENT DATA

The basic information imported to the POP&C database was a large set of incident/accident records, provided by INTERTANKO, who had originally obtained most of this data from LMIS Ltd. The data concerned all subtypes and sizes of tankers and covered the period 1978 to early 2004.
With respect to the POP&C project, the analysis of historic incidents/accidents was focused on records pertaining to AFRAMAX tankers\(^1\), defined as tankers with DWT in the range 80,000 – 119,999. In addition to this size extract criterion, only certain AFRAMAX subtypes were selected for further investigation, namely: Oil Tankers, Crude Tankers, Shuttle Tankers, Product Carriers and Chemical/Oil Tankers. On the other hand, OBOs, Ore/Oilers and Chemical Tankers were excluded from the present analysis, because these tanker subtypes have special design/layout and operational features, which are not representative of the whole AFRAMAX class of tankers.

2.2 DATABASE CONSTRUCTION

The initially selected records were imported into a database designed by NTUA-SDL to enable a comprehensive analysis of the data. The POP&C Database has been set-up in MS ACCESS 2000 format.

The structure of the database enables the analyst to register numerous complementary codes derived from the review of the available textual information in a user friendly manner (using checklists, pull-down menus, etc.) so that the information can subsequently be easily retrieved and systematically analysed. It also enables the complete or partial population of the POP&C Risk Contribution Fault Trees (FTs) and Event Trees (ETs) developed by the project.

The process of populating the POP&C database was carried out by the authors. Each partner organisation undertook the task of studying the accompanying complementary textual information for a number of incident and accident records and entering the relevant information in the format specified above. Because of the fuzzy character of the majority of the available information of the records, and also in order to ensure the non-biased assessment of the records to the extent feasible, a second round review of all records was conducted, by exchanging the records between the analysts.

A fuller description of POP&C database as well as a first analysis of the results has been presented in [3].

2.3 CRITICAL REVIEW OF CASUALTY DATABASES

The POP&C incident/accident categorisation represents significant deviations from the categorization adopted in the LMIS database, which to a large extent has become an industry standard over the years. For example, “Fire and explosions” are treated as one category in LMIS and in other data sources. Upon examining the causes and consequences of fire and of explosion accidents, it is realised that these differ considerably and because the scope of the analysis is to use this information on risk-based methodologies, it was considered essential to define accurately the first, initiating event. Therefore the particular events were investigated separately.

LMIS database has also a category called “Hull and Machinery” which incorporates structural failures, failures of machinery and propulsion devices, and failures of hull and deck fittings, all of which should be rationally examined under separate categories as they are associated with different Fault Trees and Event Trees. In the POP&C database, the corresponding one accident and two incidents were analysed under the following three separate categories, namely Non-Accidental Structural Failure (LOWI, see below), Failure of Hull Fittings (non-LOWI), and Machinery Failure (non-LOWI).

In addition, contact accidents (collision between a tanker and a fixed installation or a floating object) were separated from collision accidents because they differ as an accident mechanism from ship to ship collisions. Furthermore, as implied earlier each major accident category was subdivided by a unique sequence of subcategories and complemented by descriptions of causes and consequences, all of which follows the POP&C Risk Contribution Fault Trees and Event Trees developed by the project.

For the purpose of the POP&C analysis, accidents are classified according to the six Loss Of Watertight Integrity (LOWI) categories (see Table 1). This categorisation is done in accordance to the resulting event, such that, for example, failure of steering equipment resulting in grounding is classified as a grounding event. Furthermore, failure of steering equipment which does not lead to one of the six events is assigned to a category outside the six LOWI categories, as also are cases of failures of hull and deck fittings which do not lead to LOWI (all these are also termed here as “incidents”).

Event location, oil spill location and ship’s operating conditions at the time of the incident/accident are properly described according to IMO formal relevant description. Where available, detailed oil spill information, environmental condition at that time of incident/accident (sea state /wind force) and description of the outcome of the incident/accident with respect to the vessel’s condition, such as no sustained damage, sustained damage requiring minor or major repairs, total loss, etc, are also recorded in POP&C database.

3. RATES OF ACCIDENTS

The main scope of POP&C project is to evaluate accidents that potentially could lead to ship’s loss of

---

\(^1\) Complementary studies on SUEZMAX, VLCC & ULCCs were and are conducted by the Ship Design Laboratory of NTUA in parallel to the POP&C project [6], [7]
watertight integrity (LOWI), therefore the calculation of accident rates was focused on the six newly predefined major accident categories, namely: Collision, Contact, Grounding, Non-Accidental Structural Failure, Fire, and Explosion accidents all of which have the potential to lead to ship’s LOWI. Table 1 presents the distribution of the accident categories under investigation pertaining to AFRAMAX tankers.

Table 1: Newly predefined accident categories according to POP&C analysts

<table>
<thead>
<tr>
<th>POP&amp;C Accident Category</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision</td>
<td>233</td>
<td>29</td>
</tr>
<tr>
<td>Contact</td>
<td>126</td>
<td>16</td>
</tr>
<tr>
<td>Grounding</td>
<td>194</td>
<td>25</td>
</tr>
<tr>
<td>Non-Accidental Structural Failure</td>
<td>121</td>
<td>15</td>
</tr>
<tr>
<td>Fire</td>
<td>79</td>
<td>10</td>
</tr>
<tr>
<td>Explosion</td>
<td>39</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total of six studied categories</strong></td>
<td><strong>792</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

3.1 ACCIDENT RATES PER SHIPYEAR

For all six accident categories, the accident rates per ship year were calculated by dividing the number of accidents to the number of ships operational in that year (AFRAMAX fleet at risk). It was evident that the overall frequency of accidents (considering all six categories) was significantly reduced for the post-1990 period, Figure 1. The straight lines in the relevant figure represent the average values of accident rates for the particular reference period. The same conclusion can be drawn by studying each accident category separately [4].

Taking into account only the accidents that led to serious and catastrophic (total loss) consequences (S-TL), the frequencies exhibit similar downward trends for all the accident categories investigated. In Table 2, the average values of rates are presented for pre and post-90 periods. It is noted that in the post-90 period, not only the number of accidents was reduced but also the number of accidents with serious and catastrophic (total loss) consequences was reduced to almost the same extent.

Table 2 Average values of rates of all accidents and accidents with S-TL consequences for pre & post-90 periods

<table>
<thead>
<tr>
<th>Period</th>
<th>Accidents rates</th>
<th>Rates of accidents with S-TL consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-1990</td>
<td>1.15E-01</td>
<td>2.37E-02</td>
</tr>
<tr>
<td>1991-2003</td>
<td>3.81E-02</td>
<td>7.28E-03</td>
</tr>
</tbody>
</table>

This significant improvement in the safety record of the AFRAMAX tankers may be considered to be the result of stricter international regulations enacted in the early 1990s and advances made in design and safe operation of tankers. One such regulation was the mandatory introduction of double hull tanker design and gradual phase-out of single hull tankers as the requirement of OPA 90 and MARPOL. However, it will be unrealistic to assume that the introduction of double hull tankers is the key reason for this improvement since the double hull tankers were introduced to the market gradually and moreover only 18.5 % of the fleet at risk forms the double hull segment of the total AFRAMAX fleet for the period analysed. Furthermore, the major improvement that could be expected from the introduction of double hulls should be in reducing the consequences of incidents/accidents and not necessarily in reducing their frequency.

A series of IMO regulations concerning the prevention of incidents and accidents have apparently contributed to this improvement. A separate study was conducted [5] concerning the influence of regulations on the safety record of AFRAMAX tankers. According to the study, some key regulations appear responsible for the declining trends of accident rates.

3.2 RATES OF ACCIDENTS LEADING TO POLLUTION

Taking into account accidents that caused environmental pollution, independently from the quantity of oil spilt, it is evident that the rate of accidents leading to pollution also declined during the studied period, but not to the same extent as in the case of all accidents. The straight lines in Figure 2 represent the average value of accident rates for different periods.

Studying these environmental pollution rates for each accident category, it was also found that they have been reduced for the post-90 period, except in case of Non-Accidental Structural Failure accidents, which have slightly increased in the post-90 period.

3.3 SPILLED TONNE RATES

When the oil spill quantity is taken into consideration in calculating the rates per shipyear, the picture is somewhat different. Although the frequency of accidents has been substantially reduced in the post-90 period, there is no reduction in spilled tonne rates in the same period, but even an increase (average values of reference periods), see Table 3.

Figure 3 shows the spilled tonne rates per shipyear for the period of analysis. As can be seen from the figure, high spilled tonne rates were experienced in the following three years: 1980, 1993 and 2002. This is not related to a high frequency of accidents resulting to pollution, but to one individual casualty per mentioned year with serious environmental consequences, namely “IRENES SERENADE” (80,000 t spilled, 1980), “BRAER” (88,214 t spilled, 1993) and “PRESTIGE”

---

2 There is confusing information in various sources regarding the actual spillage of this ship, however the herein assumed value appears the most reliable one, as it is in line with the payload capacity of the referenced ship.
(77,000 t spilled, 2002). These observations lead to the conclusion that although the frequency of accidents (with or without pollution) has been significantly reduced (risk probability), the risk consequence to the environment has been slightly increased. Nevertheless, it must be recognised that it is not safe to draw firm statistical conclusions on the basis of three major spill events in a period spanning a quarter of a century.

Table 3 Average rates of accidents with oil spill occurrence & spilled tonne rates.

<table>
<thead>
<tr>
<th>Period</th>
<th>Rates of accidents with oil pollution</th>
<th>Spilled Tonne Rate per shipyear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-2003</td>
<td>5.54E-03</td>
<td>32.5</td>
</tr>
<tr>
<td>1978-1990</td>
<td>6.74E-03</td>
<td>29.6</td>
</tr>
<tr>
<td>1991-2003</td>
<td>4.35E-03</td>
<td>35.4</td>
</tr>
</tbody>
</table>

Figure 1: Accident rates per shipyear of six accident categories

Figure 2: Rates of accidents leading to pollution per shipyear

Figure 3: Spilled tonne rates per shipyear
4. SHIP’S OPERATING CONDITIONS AT THE TIME OF THE EVENT

A separate investigation was conducted with respect to the ships’ operating conditions at the time of the 1290 recorded events (792 LOWI accidents and 498 non-LOWI incidents).

4.1 EN ROUTE

In total, 577 events (45% of total) occurred while the vessel was sailing. The distribution of these events into major incident/accident categories was as follows: 30% were machinery failure, 25% were grounding, 14% were collision, 9% were non-accidental structural failure, 7% were failure of hull fitting, 6% contact, 5% fire, 2% were explosion and 2% were attributed to unknown reasons.

The following distribution of the events’ degree of severity was found: 74% were non-serious, 24% were serious whilst 2% resulted to ship’s total loss.

Considering the environmental pollution, in 94% of the events no oil pollution occurred, in 1% of the events the amount of spill was less than 7 tonnes, in 2% of the events the oil spill quantity was between 7-700 tonnes, and in 3% of the events the oil spill was greater than 700 tonnes.

4.2 DISCHARGING

In total, 56 events (4% of total) occurred while the vessel was discharging its cargo. For these events, the distribution of major incident/accident categories is as follows: 33% were failure of hull fitting, 20% were collision, 16% were machinery failure, 11% were non-accidental structural failure, 7% were fire, 5% were explosion, 2% contacts, 2% grounding and 4% were attributed to unknown reasons.

The following distribution of the events’ degree of severity was found: 79% were non-serious, 19% were of serious nature whilst 2% resulted to total loss of ship.

Considering the environmental pollution, 63% of the events resulted to no oil pollution, in 21% of the events the amount of oil spill was less than 7 tonnes and in 16% of the events the resulting oil spill quantity was between 7-700 tonnes.

4.3 MANOEUVRING

Forty-six (46) events (4% of total) occurred during ship’s manoeuvring operations. For these events, the distribution of major incident/accident categories is as follows: 59% were contacts, 33% were collisions, 4% were failure of hull fitting, 2% were non-accidental structural failure and 2% were machinery failure incidents.

Five events out of 46 (11%) were characterised with serious-degree of damage. The rest of the events (89%) resulted in non-serious damage. There were ships’ total losses.

In 5 out of 46 events, an oil spill occurred. In 2 of these, the total oil spill quantity was less than 7 tonnes, 2 events resulted to oil spills between 7-700 tonnes and the oil spill quantity was greater than 700 tonnes in one event.

4.4 UNDER REPAIR AND CONSTRUCTION

Twenty eight (28) events (2% of total) occurred while the vessel was under repair or construction. The majority of these events were “Fires” (57%), and “Explosions” (36%).

Focusing on Fire accidents (16 out of 28), only 2 were characterised with serious degree of damage, whereas the rest resulted in non-serious damage. Fire started from internal sources in all registered cases. According to the database, the cause of fire ignition was “hot works” in 15 cases out of 16. In 10 cases, the fire started at cargo/slop tanks. In one case out of all fire accidents, an explosion was followed as the second major event.

The consequences of explosion accidents were found to be more severe when compared to fire accidents. For example, one case resulted to ship’s total loss, while five accidents were characterised with serious degree of damage. The majority of explosion accidents started in the ship’s aft area (2 in Engine Room and 2 in Boiler Room) and in Cargo/Slop tanks (4 accidents). In 4 cases out of 10, the explosion was followed by fire.

One event was characterised as a collision with non-serious degree of severity. The ship under repair was damaged by another ship whilst she was mooring alongside. Another incident occurred because of failure of hull fittings. It was characterised by serious degree of severity and resulted in major ship repairs.

As can be expected from the ship’s operating condition, no environmental damage due to oil pollution occurred in these particular events. The characterisation of the events as serious was due to the consequences to human life (loss of lives-serious injuries) and/or loss of property (major repairs, total loss).

5. EVENT LOCATION

The specific event location was then investigated and results are presented in the following section.

5.1 IN OPEN SEA
In total, 280 incidents/accidents took place in open sea. The distribution of these events is as follows: 41% were machinery failure, 18% were non-accidental structural failure, 13% were failure of hull fittings, 11% were collisions, 6% were fire, 5% were explosion, 3% were contacts and 3% were attributed to unknown reasons.

In terms of degree of severity of the outcome of these events, 75% were of non-serious nature, 23% were serious, whilst 2% resulted in ship’s total loss.

Considering the environmental pollution, no oil pollution occurred in 97% of these events, in 1% of the events the oil spill amount was less than 7 tonnes, in another 1% the oil spill quantity was between 7-700 tonnes, and a further 1% of these events resulted to oil spill amount greater than 700 tonnes.

5.2 IN COASTAL WATERS

In total, 207 incidents/accidents took place in coastal waters. The distribution of these events is as follows: 37% were collisions, 29% were grounding, 13% were machinery failure, 12% were contacts, 4% were fire, 3% were failure of hull fittings, 1% was explosion and 1% was non-accidental structural failure.

In terms of degree of severity of the outcome of these events, 74% were of non-serious nature, 22% were serious, whilst 4% resulted in total loss of ship.

Considering the environmental pollution, no oil pollution occurred in 93% of these events, in 1% the amount of oil spilled was less than 7 tonnes, in 4% of the events the oil spilled was between 7-700 tonnes, whilst in 2% of the events the oil spill amount was greater than 700 tonnes.

5.3 AT PORT

According to POP&C database, 179 incidents/accidents took place at Port. The distribution of these events into major incident/accident categories is as follows: 25% were contacts, 24% were collisions, 17% were fire, 10% were failure of hull fitting, 8% were grounding, 7% were explosion, 5% were machinery failure, 2% were non-accidental structural failure whilst 2% were attributed to unknown reasons.

In terms of degree of severity of the outcome of the events, 86% of these were of non-serious nature, 12% were serious, whilst 2% resulted to ship’s total loss.

Considering the environmental pollution, in 90% of the events no oil pollution occurred, in 6% the amount of oil spill was less than 7 tonnes, in 3% the oil spill amount was between 7-700 tonnes, and in 1% of these events the oil spill was greater than 700 tonnes.

6. RELATIONSHIP BETWEEN HULL TYPE AND OIL SPILLS

The relationship between the oil spill data and the hull type was investigated considering different hull configurations. In view of the space limitation, this paper concentrates on results for double hull and non-double hull tankers. In this context, Double Hull (DH) is herein defined as the full double hull concept according to currently in force MARPOL requirements, whereas the Non-Double Hull (Non-DH) definition includes besides the single hull tankers, also the double bottom and the double side skin tankers.

Figure 4 presents the percentage of ships involved in pollution accidents by hull type. Based on the results of Figure 4, it can be stated that the percentage of DH ships involved in accidents causing oil pollution is comparable to that of Non-DH ships (8.0% versus 7.4%). However, this statistic might be misleading, as it does not provide any information on the amount of oil spilled by the two hull types.

Table 4 presents synoptically the amount of environmental pollution within the period 1978-2003 by ship’s hull configuration and a pollution index that is the ratio of the sum of the quantities of pollution in a given period over the sum of shipyears at risk in the same period. The numerical values presented in Table 4 differ to those in Table 3, as Table 3 is the average of annual spill rates over a given period (i.e. it is a sum of ratios).

Table 4 shows that although the relative percentage of DH tankers involved in accidents with oil spill is comparable to that of Non-DH ships, the resultant oil spill amounts per shipyear for DH tankers is significantly smaller to the corresponding rates of non-double hull configurations.

Table 4 also presents a comparison of pollution rates (tonnes/shipyear) for the pre and the post-90 periods. It is noted that the pollution rates of the whole fleet show a modest increase, while the increase for Non-DH ships is substantial.
Commenting on the data of Table 4, oil pollution rates for tankers with Double Hull configuration are near zero and orders of magnitude smaller than those obtained for non-double hull tankers. Although these pollution rates are drawn from founded statistics of past accidents over an extended period, and hence reflect the reality so far, it may be too early to draw reliable conclusions from it, as to the actual impact of tanker hull type on pollution. One main reason for this reservation is that these rates change drastically by individual catastrophic accidents. That is to say, although oil pollution accidents involving double hull tankers so far did not result in large quantities of oil spills, on the other hand it would only take one major double hull tanker catastrophe to dramatically change the DH pollution rate. In addition, the resultant increase in the pollution rate will be further amplified because of the DH pollution rate. In addition, the resultant increase in the pollution rate would increase to about 36 tonnes per ship/year, while the index of all tankers (DH+Non-DH) would rise to 46.6.

The historic analysis of accidents presented in this paper was performed in order to populate the POP&C Fault Trees and Event Trees with the necessary frequencies and consequences data. The populated FTs and ETs will then be used to conduct the risk assessment of the AFRAMAX fleet. As discussed earlier, the POP&C database was designed in a manner that helped the analysts to code through drop down menus and checklists the key information that could be extracted from the narrative of each incident/accident’s record. In effect the resultant codes, like stepping stones, aim to define the sequence of events in each accident. The events leading up to the accident are part of the Fault Tree and define the Frequency (Probability) of the accident, while the events after the accident belong to the Event Tree and define the Consequences of the accident (consequence and its magnitude, on life, environment, and property).

The needs of POP&C for historic marine incident/accident data are common to the needs of an increasing number of other projects and analyses. Progressively, risk assessment is gaining wider acceptance in the industry as an engineering tool to assist operational decisions, while it is also gaining wider acceptance amongst the regulators (consider for example the employment of the Formal Safety Assessment methodology by IMO). Consequently we should expect an increasing demand of marine incident/accident data by our profession.

Unfortunately, the marine incident/accident databases which have evolved over the years were not designed with the application of risk assessment in mind, and therefore suffer from a number of serious limitations which make their usage in engineering projects very problematic. In the POP&C project we were blessed with sufficient resources and a sufficient number of enquiring minds to make unnecessary the taking of shortcuts. Even so, our effort to utilize the LMIS database (which is and will be the largest international accident database for the foreseeable future) in order to populate our Fault Trees proved somewhat futile. We were only able to populate confidently the top events of the fault trees, while thereafter we felt that the reliability of the statistics declined dramatically with each level of the Fault Tree we moved away from the top event. Therefore in order to be able to populate the POP&C FTs and the ETs we were forced to adopt a mixture of historic data and “expert opinion”, with quite a heavy bias towards the expert opinion. No doubt the same solution is practiced in other similar projects.

Looking to the future, the increasing application of risk assessment and the increasing need for good quality, and in plentiful supply, marine incident/accident data are probably not in dispute. What may be in dispute, or at least in need for good debate, is the method of
coding marine incident/accident records. Earlier on we mentioned some simple examples of difficulties we have had with the LMIS incident/accident codes (categories); which codes incidentally appear to have been adopted by other databases too. In fact there are more serious coding issues to be resolved. In the LMIS database incidents/accidents are assigned a single category, such as collision, grounding, fire, explosion, etc. This one-dimensional categorisation ignores the basic fact that accidents are sequences of undesirable events. Each of these underlying events has its own probability profile. For example, a fire can lead to loss of power or steering, which in turn can lead to grounding. Using a single code to define an accident takes away vital information for any subsequent analysis and is an unnecessary restriction. From the above we conclude that accident categorisation (i.e. the taxonomy) is in need of a serious rethink and restructure.

Here we propose one possible approach for creating a taxonomy which would address the limitations identified during the POP&C analysis. The basic idea is to adopt a cascade of codes each defining a different stage of the incident/accident.

Because the primary root causes of casualties are rarely defined in incident/accident databases, an alternative approach is needed whereby the categorisation of casualties is defined at the instance of the “Primary Manifestation of the Failure” (i.e. when it becomes evident that something has gone seriously wrong). The first code would therefore define: the Primary Manifestation of Failure (which for example could be Loss of Steering, or Loss of Propulsion, or Loss of Power, Equipment Malfunction, Anchoring or Mooring problem, Structural Failure, Cargo Shift, etc). The second code could be a subcategory of the first code (such as for example in the case of Loss of Steering it could be Rudder, or Steering Gear; whereas in the case of Loss of Propulsion it could be Main Engine, or Transmission, or Propeller; etc). The third code will describe the Outcome (and here suitable categories are Collision, Grounding, Contact, Loss of Watertightness, Listing, Foundering, Accident to Human, etc). The fourth code finally would describe the Consequence of the accident (such as damage to humans, to environment, and to property; each of these given a magnitude of consequence so as to provide information on a severity scale). In summary, the sequence of codes in the proposed taxonomy would be:

- Primary Manifestation of Failure (PMF)
- Subcategory of PMF
- Outcome
- Consequence

Note that the physical event defined under “Primary Manifestation of the failure” could be termed “the incident”, but in some sense it is the Outcome which turns an “Incident” into an “Accident” or “Casualty”, as for example, loss of steering is an incident, but it is a resultant grounding which turns this sequence into an accident/casualty. On the other hand loss of propulsion which is remedied before any further adverse event should be termed an incident and not a casualty.

According to the proposed taxonomy a given casualty may be characterized by more than one Outcome and/or Consequence (eg [Loss of Steering] - [Rudder] - [Grounding + Explosion] - [Damage to Environment + Damage to Property]). It is thought that the proposed taxonomy could provide the mechanism for routine analysis of a populous marine accident database so as to identify problems, trends and their consequences.

8. CONCLUSIONS

For all AFRAMAX tankers, the accident rate per shipyear has reduced significantly when considering pre and post 1990 accidents (by a factor of about 3, as seen in Figures 1 and 5). However, the rate of accidents leading to pollution per shipyear has reduced by a less significant amount (by around 35%, as seen in Figures 2 and 5, also in the data of Table 3).

Careful review of the data of Tables 3 and 4, shows that the total oil pollution quantity in the post-90 period was 63% of the total pollution quantity of the entire period considered in the analysis. Because the number of ships at risk was significantly larger in the post-90 period, this led to the 35% reduction to the rate of accidents leading to pollution. However, as mentioned earlier, because of 2 registered catastrophic accidents in the post 1990 period, compared to 1 in the period before, the Spilled Ton Rate per shipyear has even increased by 20%.

Regarding the relation between hull configuration and oil spill occurrence, double hull AFRAMAX tankers have yielded a remarkably smaller pollution quantity per shipyear in comparison to the non-double hull tankers, while, as expected and as seen in Figure 4, the frequency of accidents leading to pollution is almost the same for double and for non-double hull tankers.

With respect to the above conclusions, it should be noted that the analysis does not yet account for the
impact of ship age on the various accident categories and on their consequences. Thus, particular conclusions on the actual performance of hull types should be made carefully, keeping in mind the different age structure of the hull types being compared.

9. ACKNOWLEDGEMENTS

A major part of the study presented herein, was financially supported by the European Commission under the FP6 Sustainable Surface Transport Programme. The support is given under the scheme of STREP, Contract No. TST3-CT-2004-506193. The European Community and the authors shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof. The authors must also acknowledge their project partner Lloyd’s Register for providing comprehensive data for the fleet at risk throughout the period of analysis.

10. REFERENCES


11. AUTHORS’ BIOGRAPHIES

Apostolos Papanikolaou Professor Dr.-Eng. Habil., is Director of Ship Design Laboratory of NTUA. His educational, research and professional activities cover a broad area of naval architecture and ocean engineering. He was and is Principal Investigator of a large variety of funded R&D projects related to the design and optimization of conventional ships and advanced marine vehicles, the hydrodynamic analysis and assessment of the calm water and seakeeping performance of ships and floating structures, the logistics-based and risk-based ship design, the stability and safety assessment of ships and related national and international regulatory developments (IMO).

Eleftheria Eliopoulou is a graduate of the Department of Naval Architecture and Marine Engineering, NTUA and currently Dr.-Eng. Candidate at the Ship Design Laboratory of NTUA. She is working on research fields related to ship design and ship’s damage stability and survivability.

Nikos Mikelis (MSc, PhD, FRINA) is an independent consultant naval architect. He works for INTERTANKO as the coordinator of the POP&C project.

Seref Aksu (BSc, PhD) holds the current position of lecturer at the Department of Naval Architecture and Marine Engineering, Universities of Glasgow and Strathclyde. He is involved with research in fields of structural dynamics, structural reliability, hydroelasticity and slamming. His previous experience includes motions and responses of high-speed vessels, through life structural management of naval vessels.

Severine Delautre is Graduated Engineer of Ecole Centrale de Nantes in 2002. She holds the current position of Risk Analysis Engineer at the Risk Engineering section at Bureau Veritas Marine Division. She is currently working on safety related R&D projects.