A Critical Review on the Role of Ship Stability in Accidental Oil Spillage

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SUMMARY

The Erika (1999) and the Prestige (2002) incidents have caused major pollution on European waters and have increased society's awareness of tanker safety and implications of the damage to environment due to accidental oil spillage. As a result of the increased public pressure, international regulations have been tightened yet again without rational risk analysis. This often means that decisions are taken quickly having limited information in hand; hence new regulations are only leaves so long until another major accident occurs. Any critical gap in the regulatory regime or in a wider context under any safety assessment methodology must be identified and be dealt with in an integrated manner. To this end the role of stability, from both intact and damaged tanker point of view, must be clearly identified in relation to every critical hazard systematically. This paper discusses the role of stability from the point of view of the statistical information obtained from the past accident records. In particular, the accident data pertaining to *Total Loss* and *LOWI* for AFRAMAX tankers was examined in depth.

NOMENCLATURE

IMO – The International Maritime Organization and it's various technical subcommittees such as the SLF (Sub-Committee on Subdivision, Loadlines and on Fishing Vessels).

MARPOL 73/78– In short form the International Convention for the Prevention of Pollution from ships 1973, as modified by the Protocol of 1978. Marine Pollution From the standpoint of damage survivability the term generally refers to ships with large un-subdivided horizontal spaces.

POP&C – the acronym for Pollution Prevention and Control project, supported by the European Commission under the thematic priority-Sustainable Development, Global Change and Ecosystems, Sustainable Surface Transport Programme of the FP6. Contract No. FP6-PLT-506193.

INTERTANKO –is the International Association of Independent Tanker Owners.

AFRAMAX – the short name for a tanker ship of standard size, originally abbreviated from American Freight Rate Association, approximately 80,000 - 120,000 DWT.

LOWI – the acronym for Loss of Watertight Integrity; that is used to describe the situation where hull shell is breached, and directly or indirectly oil spill may occur as a result.

p-factor – the probability that only the compartment or group of compartments under consideration may be flooded.

s-factor – the probability of survival after flooding of the compartment or group of compartments under consideration.

1. INTRODUCTION

Stricter international regulations adopted in the early 1990s and advances made in design and safe operation of tankers provided a significant improvement in the tanker industry safety record. According to The International Tanker Owners Pollution Federation, oil pollution from tankers for the period 1997-2003 was only 25% of the pollution for the period 1990-1996. The total number of reported tanker incidents with pollution for the period 1997-2003 was only 37% of the figure for the period 1990-1996, while at the same time the total oil trade has increased by about 15%. On the other hand, two particular accidents have changed the tanker industry's good record. The cause and effect of the Erika (1999) and Prestige (2002) incidents, with their heavy oil cargoes causing extensive pollution on European shores, have had major political, social and economic implications.

Single hull tankers are gradually being phased out according to the IMO's global regime for more than ten years, but two years back Europe went beyond international regulations and implemented a unilateral accelerated phase-out, which has since led to the international phase-out being accelerated too. The control system for tankers has also been tightened up at the same time as the industry itself has taken initiatives to ensure that the structural integrity of tankers is maintained to good standards throughout the life of the ships.

Despite all these efforts accidents of various type and scale will continue to occur with a degree of risk yet to be measured rationally. Nonetheless, stability of the vessel will continue to be an important factor in deciding the likelihood of an event of accidental oil spillage caused by tankers. Both intact and damage stability will play their roles whether through total loss of the vessel or partial loss of watertight integrity of the hull. This certainly places a question on the realisation of the role of ship stability in accidental oil spillage. In order to enlighten an answer to this question it is necessary to have a critical look at the historical accident records. To this end, this paper attempts to do this by utilising available accidental record analysis carried out during the POP&C project.

2. POP&C PROJECT

The POP&C project aims to address the recent marine accidents and related issues by focusing on prevention and mitigation in ship design and operation for existing and new vessels. The specific objectives of POP&C include developing a risk-based passive pollution prevention methodology and developing a risk-based active post-accident pollution mitigation and control framework [1]. In achieving the main objectives of the project the first work carried out included identifying and ranking critical hazards involving tankers. The project consortium has built a generic risk model which focuses on incidents/accidents that can potentially lead to a vessel's loss of watertight integrity and which in turn consequently can cause oil spill pollution. To this effect six main categories of accidents were identified; namely contact, collision, grounding, fire, explosion and non-accidental structural failure. The development of the main hazards model has been supported by the development and analysis of a tanker accident database which consists of about 1300 AFRAMAX tanker accidents records for the period 1978 to 2003. The relationship between various hazards, main causes and prevailing frequencies of occurrences were derived from the database. Considering the limited time and resources the scope of the project included only AFRAMAX type tankers. For further information on the project see reference [1].

One of the critical assumptions, taken in the project is that a significant amount of accidental spill could occur due to loss of watertight integrity of the hull and any other incident causing oil spill primarily involving issues of on deck operations could widen the scope of the project beyond the resources allocated. This immediately brings the prospects of damage stability under the spotlights for consideration together with the above said accident categories. Therefore one of the main decider in determining the amount of oil spill is whether the vessel stays upright or capsizes after an accident.

3. INCIDENTS CONCERNING THE AFRAMAX FLEET

The POP&C project has compiled and systematically analysed accident database which was made available to the consortium aiming at ascertaining the following:

- To determine the main categories of accidents that lead to potential oil spill
- To establish primary causes of main accident categories and frequency of occurrence through fault tree analysis
- To determine the most likely chain of events following the main accidents together with their probability of occurrence through event tree analysis

3.1 SOURCE OF ACCIDENT DATA

The original raw data was provided by a comprehensive set of accidental records of INTERTANKO. The INTERTANKO database is a tanker casualties' database containing 16,554 records of worldwide tanker ships casualties covering the period 1978 to early 2004 [2].

Table 1: The original accident categorisation and respective number of records

LMIS Incident Type	No. of Incidents
Hull and machinery	615
Collision	363
Grounding	192
Fire/Explosion	118
Miscellaneous	22
Total	**1310**

Out of all the 16,554 available records, it was decided to focus the analysis on the AFRAMAX tankers only, which constituted 1310 records, see Table 1.

3.2 TANKER ACCIDENT CATEGORIES

After the review and analysis of the database, POP&C has concluded the incident/accident types in nine separate categories, and distributed all the reliable data entries to the respective category, see Table 2.

Following the assumptions taken earlier, pertaining to spillage potential and keeping design perspective in mind, for further analysis 6 main accident categories out of 9 categories has been selected; namely collision, contact, grounding, fire, exploration and structural failure (non-accidental). These are inline with the main focus of the project. Although the biggest contributor is "machinery failure" with 26%, it is intentionally left out as the accidents in this category will not create potential oil spillage directly as a primary reason.

Table 2: The accident categorisation according to POP&C database and respective number of incidents

POP & C Incident Type	No. Of Incidents	Percentage
Machinery Failure	337	26%
Collision	233	18%
Grounding	194	15%
Failure of Hull Fittings	137	11%
Contact	126	10%
Structural Failure	121	9%
Fire	79	6%
Explosion	39	3%
Unknown Reasons	28	2%
Total	**1293**	**100%**

A rigorous analysis into incident/accident records with necessary cross-checks has been undertaken and completed, furthermore main results have already been published in the public domain [3], [4]. In addition to work carried out within the POP&C project, the author has analysed records of accidents in relation to cases of LOWI and total loss, and from which the results presented in this paper are produced.

4. TOTAL LOSS

It is not clear from the accident records that any AFRAMAX tanker has capsized or lost due to poor stability in intact conditions as the primary cause during the period under consideration (1978-2003). It is essential to check each individual accident reports to be sure about this argument however public domain information is suggesting that there is not enough evidence to support that intact stability causes directly total loss of tankers. There are a number of non-AFRAMAX size tanker accidents that are mostly contributed to total loss in extreme weather conditions or capsize due to mistake/failure in operations such as wrong ballasting, over loading.

All the accidents reported as total loss or capsize in the POP&C database are those that are involved in an extensive damage to hull structure so much so that it resulted in capsizing/sinking a part of or the whole of the hull. The matter is different under the conditions where the damage stability is the primary concern. The analysis of the database provided the number of incidents resulting in total loss in relation to incident type, which is summarised in Table 3. It is more likely to expect total loss due to grounding as 3.6% of the grounding incidents resulted in total loss of the vessel.

Total loss occurs mostly due to breaking up of the vessel and sinking of all or some of the break away sections of the hull structure. The cases, which later on decided that vessels should been decommissioned -probably due to extensive repair work being required-, are not include in this effect.

Table 3: The cases of total loss per accident category – number of incidents and percentile within relevant category

POP & C Accident Type	No. of incidents resulting in Total Loss	Percentage in the relevant category
Collision	1	≈ 0.4 %
Grounding	7	3.6%
Contact	0	0%
Structural Failure	3	2.5%
Fire	1	≈1%
Explosion	1	≈2.5%

5. LOSS OF WATERTIGHT INTEGRITY

It is intuitive that loss of watertight integrity (LOWI) brings some concern on stability in damage conditions. Unlike the uncertainties of stability in intact conditions, in damage conditions given that the damage on the outer hull is described clearly one can easily reproduce the conditions of the damage, and estimate potential effect on evolving conditions of the accident outcome. The POP&C project has taken occurrence of LOWI as the main condition where oil outflow potential is paramount. Therefore in parallel damage stability has to be considered to determine the amount of oil that could spill in given conditions. In particular principles of probabilistic damage stability could be utilised through the relevant p-factor that is produced with the help of the methods employing the first principles such as collision accident simulations, or historical data of tanker accident statistics such as MARPOL's collision and grounding damage location and extent distributions.

From the accident database the number of accidents that resulted in LOWI per accident category is summarised in Table 4. It is interesting to see that given an accident that occurred from one of the main categories the probability of LOWI is the highest for contact incidents/accidents with 24%, and closely followed by structural failure with 22%. In the event of fire LOWI is the least likely to occur. Only 1% of all the recorded fire accidents for AFRAMAX have actually been reported as having LOWI.

Table 4: The cases of total loss per accident category

POP & C Accident Type	No. of incidents resulting in LOWI	Percentage in the relevant category
Collision	39	17 %
Grounding	36	19%
Contact	30	24%
Structural Failure	27	22%
Fire	1	≈1%
Explosion	6	15%

From the point of view of stability in damage conditions, the statistics suggesting that contact incidents with shallow penetration and small rapture to outer shell is the most likely incident/accident that an AFRAMAX tanker may have. Hence enforcement of design features such as double-skin or double-hull seems logical.

It is interesting to note that collision is the fourth highest likely category of accident that LOWI occurs, after Contact, Structural Failure, and Grounding. The overall frequencies of occurrence of LOWI per main accident category are presented in the form of occurrence per ship-year in Table 5; and sorted in the order of frequency. The fleet at risk for AFRAMAX tankers for the period of 1978-2003 is calculated as 11379 ships.

Table 5: The frequency of LOWI

POP & C Accident Type	No. of incidents resulting in LOWI	No. of incidents	$f_{LOWI \mid MAIN\ ACCIDENT}$
Contact	30	126	2.09×10^{-5}
Structural Failure	27	121	1.96×10^{-5}
Grounding	36	194	1.63×10^{-5}
Collision	39	233	1.47×10^{-5}
Explosion	6	39	1.35×10^{-5}
Fire	1	79	1.11×10^{-6}

6 DISCUSSIONS

An extensive number of accident records available have been utilized to provide a greater understanding of the hazards which can potentially cause oil spillage. Most of the accident records of AFRAMAX do not indicate clearly the primary reason for total loss; it is therefore decided not to conclude upon these figures that stability will have very little effect on the fate of the tanker vessel in stress. However it is true to say that there is very little evidence from the historical data that stability - especially in the case of intact stability- plays a primary role in the total loss cases.

On the contrary damage stability plays an important role especially in deciding the amount of oil spillage given LOWI occurred, in extreme cases due to sinking of the vessel in part or as a whole following a large scale flooding or structural failure. The principles of probabilistic damage stability can provide very useful information in assessing potential oil outflow -through IMO calculation methodology of Environmental Pollution Index- of a tanker design. In assessing survival probability of a damaged tanker current form of s-factors from SLF-47 or MARPOL 73/78 requirements might be sufficient [5].

It is interesting to note that according to the frequency of LOWI, Grounding and Collision accidents rank 3rd and 4th respectively after contact and structural failure. There might be various reasons behind this pattern in particular for AFRAMAX tankers, and it may not be generalised for other types, however it is expected to be of the same order for most of the tanker fleet trading world-wide. Therefore damage stability and pollution prevention regulations should consider assessing tanker design performance under contact and non-accidental structural failure accident categories explicitly. In addition to grounding and collision accidents similar assessment methodology can be developed to prevent any particular weakness for the accidents of contact and non-accidental structural failure. Although contact damages are somehow safeguarded by establishing a good level of safety for collision accidents, it is desirable to portray a true level of safety per accident category.

7 CONCLUSIONS

In light of the foregoing discussion the following concluding remarks can be given:

- Intact stability seems to have nearly no direct effect on the occurrence of oil spill, which is particularly true for AFRAMAX tankers.
- Damage stability is an important factor in deciding the fate of the tanker ship and the amount of potential oil spillage after the occurrence of LOWI.
- Contact and non-accidental structural failure incidents/accidents must be included explicitly in the assessment of tanker design with respect to LOWI incidents therefore in damage stability analysis.

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9 REFERENCES

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