Emergency Response in Ship Flooding Casualties

Dracos Vassalos[1]

Andrzej Jasionowski[2]

[1]The Ship Stability Research Centre (SSRC), University of Strathclyde, Glasgow, UK

[2]Safety at Sea Ltd

ABSTRACT

Whilst tremendous efforts have been expended in accident avoidance leading to collision/grounding and flooding and in the design of ships to resist capsize/sinking post-accident, there is very little to show by way of a systematic approach how to deal with a flooding emergency. Damage control, evacuation, LSA, rescue are all topics attracting a great deal of attention but how all this fits in and is accounted for during the design stage and how effective these are post-accident in a way that this can be assessed quantitatively and accounted for in addressing life-cycle risk is all embryonic. An attempt to delve in this direction is presented in this paper. The concept used as a building block is ship vulnerability.

KEYWORDS

Emergency response, crisis management, flooding accidents, vulnerability management

INTRODUCTION

Recent disasters in the shipping and offshore industries (Concordia, Deep Sea Horizon) serve to demonstrate that a proper framework and process for risk mitigation of large scale accidents in the marine industry is lacking. Despite considerable advances in science and technology, leading to unique capabilities to design ships and offshore assets to high level of safety (passive means of risk reduction), development to address management of residual risk during ship operation and in emergencies is still embryonic. As a result, the last line of defence in safety provision (damage control, emergency response, crisis management, escape, evacuation and rescue) is dealt with haphazardly and hence ineffectively. This is particularly true in large-scale accidents, where failure nowadays might include ships and assets of such proportions that the potential impact on human life and the environment can completely re-shape or indeed eradicate the whole industry. Therefore, the need to address these issues systematically and methodologically is paramount. This would involve active means for risk mitigation during accidents, with on-board or shore-based decision support systems for emergency response and crisis management as well as means of escape, evacuation and rescue. This paper is an attempt to pave a way forward by presenting a holistic, methodological approach of risk reduction / mitigation during design, operation and in emergencies.

BASIC CONCEPTS

Ship Vulnerability (Vassalos, 2012)

"Vulnerability" is a word being used extensively in the naval sector but not so in the merchant shipping world. The way this term has been used by SSRC relates to "the probability that a ship may capsize within a certain time when subjected to any feasible flooding case." As such, vulnerability contains (and provides) information on every parameter that affects damage ship survivability. A simple example is provided next.

Figure 1 indicates that there are 3 possible flooding cases, following collision, of known (available statistics) frequency and calculable (available "tools") probability of surviving, say 3 hours With this information at hand, vulnerability to collision flooding of this simple example is:

0.5*0.72 + 0.35*0.01 + 0.15 * 0.99 = **51.2%**

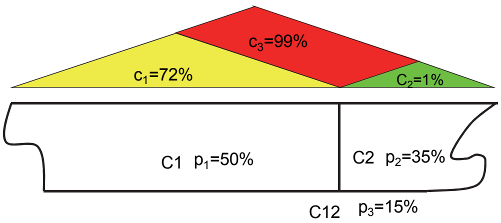

Fig. 1: Vulnerability to Collision Flooding

Vulnerability in Ship Design

The vulnerability to collision / grounding damage of passenger ships is well documented through a number of accidents claiming many lives. Such vulnerability relates to **Water on Deck** (WoD), leading to progressive flooding and rapid capsize of the ship. Whilst for Ro-Ro passenger vessels this design vulnerability is well understood, for cruise ships it has been brought to light as recently as the early 2000s. The latter case relates to the service corridor on the strength deck, which acts as conduit for floodwater to spread along the ship, leading to down flooding through deck openings / stairwells and ultimately to sinking / capsize of the ship. Figures 2 and 3 provide typical results demonstrating such vulnerability in the design of RoPax and Cruise vessels, respectively.

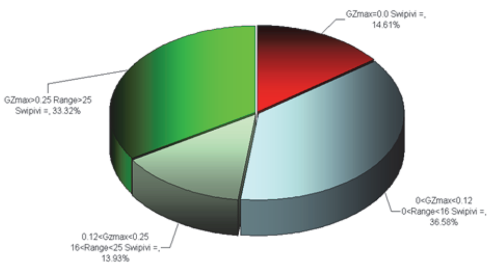

Fig. 2: Design Vulnerability (Watertight Integrity - Typical RoPax)

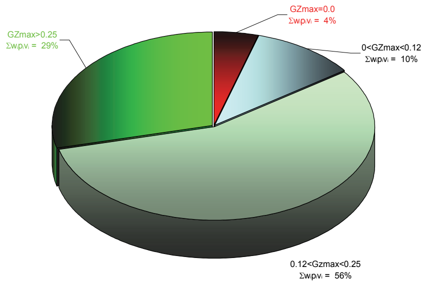

Fig. 3: Design Vulnerability (Watertight Integrity - Typical Cruise Ship)

Vulnerability in Operation

A threat that exacerbates further the design vulnerability of passenger ships to collision / grounding damage, probably at the heart of many catastrophes, is vulnerability in operation. This is an issue that has been attracting serious attention at IMO over the past few years and new legislation is now in place. It aims to address the fact that most passenger ships are operated with a number of Watertight (WT) doors open, thus exacerbating considerably the design vulnerability of these ships. Figures 4 and 5 demonstrate this rather emphatically by considering the well-known Estonia case, as designed and as operated at the time of her loss. In the latter case (because of open WT doors) the vulnerability of the vessel was at 68%; 3.5 times higher than her design vulnerability of 19%.

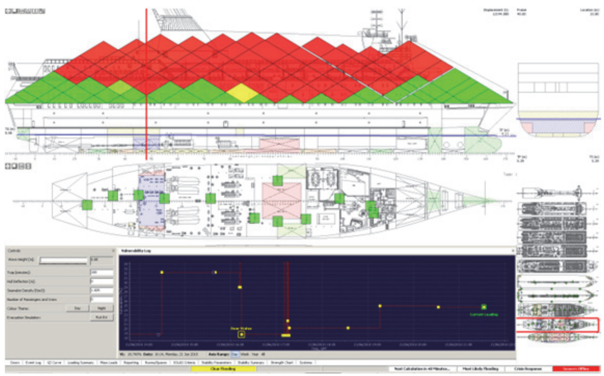

Fig. 4: MV Estonia - Design Vulnerability

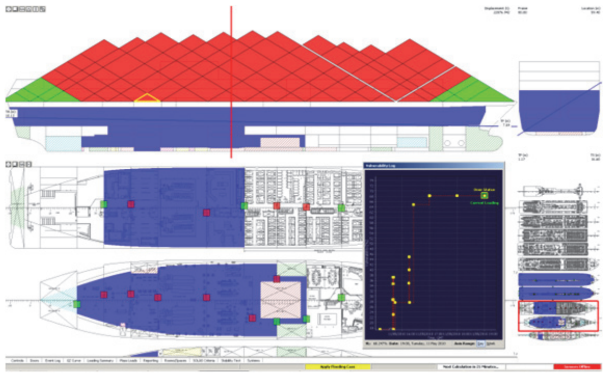

Fig. 5: MV Estonia - As Operated at the Time of her Loss

VULNERABILITY MANAGEMENT

With the view to facilitate cost-effective risk management over the life of the vessel, "Vulnerability Management" addresses this life-cycle perspective, providing, in principle, the requisite platform for an in-depth analysis and knowledge of ship vulnerability. Figure 6 shows a flowchart of the vulnerability management process, as it is currently adopted by a leading cruise operator, which is elaborated further in the following.

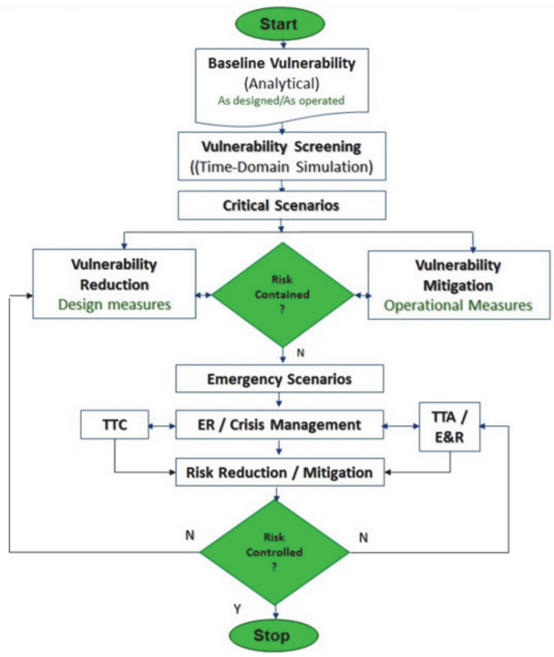

Fig. 6: Vulnerability Management: A Life-Cycle Process

Baseline vulnerability: This relates to the ship in question either as designed (all WTD closed, e.g., Figure 4) or as operated with certain WTD's open as explained in Figure 5, thus enabling WTD management. It also provides the key input for vulnerability monitoring, which in turn offers all the essential information for damage control and emergency response. The latter is facilitated especially by using an analytical technique (UGD, Jasionowski and Vassalos, 2011), producing the requisite results instantly.

Vulnerability Screening: Baseline vulnerability studies "filter out" all survivable scenarios due to collision and grounding events deriving from SOLAS-related accident statistics. For more in-depth information on the mechanics of the flooding process for critical scenarios, time-domain flooding simulations need to be used, addressing the whole flooding process (see Figure 7). Processing systematically the ensuing results allows for identification and ranking of design vulnerabilities, e.g. large undivided spaces and horizontal or vertical openings that lead to large/progressive flooding. These provide the focus for vulnerability reduction (design solutions) or vulnerability mitigation (damage control, WTD management), based on cost-effectiveness (see Figure 8).

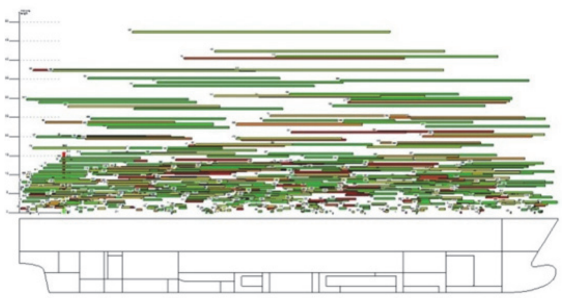

Fig. 7: Typical collision scenarios considered in numerical simulation for vulnerability screening (MC sampling of collision accident statistics)

Vulnerability Reduction (design measures / options): Using a range of tools from simple static calculations of stability and vulnerability to numerical time-domain simulations, feasible design changes with vulnerability reduction potential are examined to address the vulnerabilities identified in Step 2.

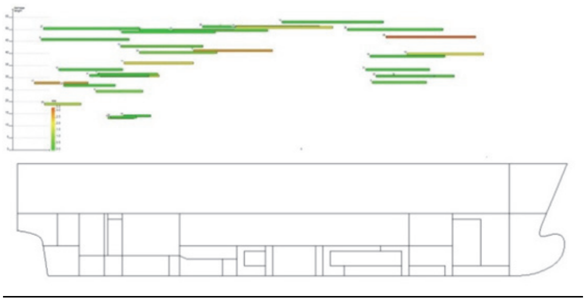

Fig. 8: Typical results following vulnerability screening demonstrating regions of weakness in design (critical scenarios)

Design changes may vary from simple internal modifications such as the installation of additional doors, introducing chamber doors, removing / relocating openings as well as rendering parts of decks watertight through structural modifications. Ultimately, the option of external modifications to the vessel, such as ducktail or sponsons, could be investigated. The impact on the overall vulnerability of each option is assessed (with regard to safety and cost) and all implications critically examined. For example, some of these design options may inherently present additional benefits, such as increased GM margins, increased deadweight capacity and reduced fuel consumption or drawbacks, such as additional weight and reduced access in addition to direct costs (see for example Figure 9). Therefore, targeted optimisation exercises may be needed.

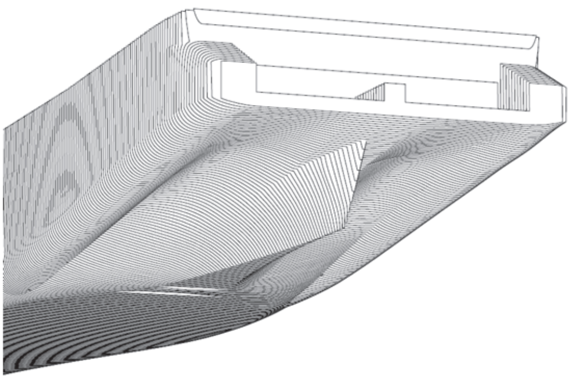

Fig. 9: Complex external modifications (Ducktail, sponsons. Skeg)

Vulnerability Mitigation (Damage Control): Vulnerability mitigation entails the use of operational measures, mainly damage control, using manual or automated counter-ballasting. This will require knowledge of the residual functionality of the related systems in each one of the scenarios in question, to enable action being taken as appropriate. This, in turn, may suggest modelling and availability analysis of such systems, and preparing crew operating manuals. Alternatively, some degree of automation (decision support) may be required to render the operation effective and time-efficient. Finally, in newbuildings, enhancing the residual capacity for counter-ballasting post flooding casualties may be one of the design requirements worth addressing. Even with the best designs today the casualties that may be rectified though damage control (counter-ballasting) is of the order of 10% (se Figure 10).

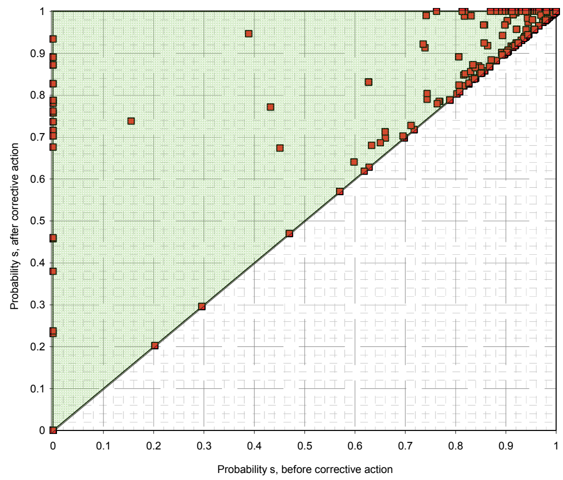

Fig. 10: Typical effectiveness of counter-ballasting post-flooding casualties in a cruise ship.

Once the aforementioned exercise is complete, there will be a limited number of scenarios for which the probability of the ship capsizing/sinking will be unacceptably high. These scenarios constitute the *emergency scenarios*.

Emergency Response (Figure 11): This relates to setting a process in place and implementing it through rigorous training to enable mobilisation of crew teams to identify, characterise and influence as appropriate the evolution of flooding and the fate of the vessel in emergencies involving large-scale flooding. The development here also involves providing timely information to crew and master for crisis management through a decision support system. This entails undertaking a risk assessment of all emergency scenarios aiming to identify potential design alternatives / refinements and/or operational arrangements to ensure that all persons on board will be able to abandon the vessel safely. This involves assessing and verifying the functionality and performance of all escape, evacuation and rescue systems / processes. The verification itself will involve estimation of time to capsize in each pertinent scenario as well as advanced escape and evacuation analysis as defined in MSC.1/Circ.1238. The assessment addresses the suitability of escape arrangements, emergency crew procedures, damage control actions, related LSA operational information and search and rescue arrangements, if known.

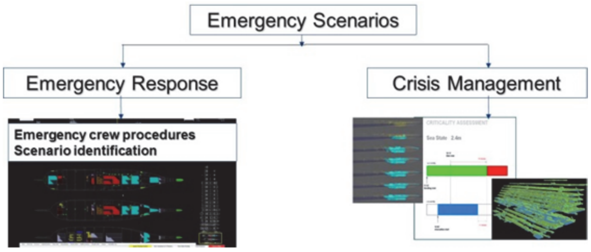

Fig. 11: Emergency Response and Crisis Management in a Flooding Emergency

Decision-making and choice of various options/measures to reduce/control risk is based on cost-effectiveness, using IMO or company-based criteria.

CONLCUDING REMARKS

- Building on the knowledge and understanding of damage stability fundamentals, a process has been elucidated to address the vulnerability to flooding of passenger ships from a life-cycle perspective and with focus on emergency response and crisis management as the last line of defence.
- The process delineates the identification of emergency scenarios and describes a systematic procedure of de-risking the people on-board by a series of design and operational measures and a rational means for decision-making based on cost-effectiveness.
- The process is holistic and equally suited to newbuildings and old ships.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the RCCL management and staff for offering them the opportunity to turn vision to concept and dream to reality.

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