Ocean Engineering 125 (2016) 342–348

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Technical note

Stability barrier management for large passenger ships

Tobias King [a], Clayton Van Welter [b], Tor E. Svensen [c]

[a] DNV GL, Miami
[b] Royal Caribbean Cruises, Ltd., United States
[c] DNV GL, Norway

ARTICLE INFO

Available online 23 August 2016

Keywords:
Stability barrier management
Barrier management
Stability management
Safety management
Passenger ships
Cruise ships
Bowtie

ABSTRACT

This paper deals with major accident risk related to stability on large passenger ships. The main scope of work is to investigate the impact stability related risk has on the total risk picture, and introduce barrier management as an approach to control stability related risk. The paper also addresses some main elements in stability management, highlights critical barriers and presents a case study on how stability barrier management may function in practise.

1. Major accident risk for passenger vessels

Several definitions of major accident exist, as described by DNV GL and the Norwegian Ship-owners Association in the report “Good Practices – Barrier Management in Operation for the Rig Industry” (Øie et al., 2014). Although somewhat different, they all have in common that they refer to large scale consequences, in terms of impact on life, property and the environment. They also indicate that the consequences may be immediate or delayed, suggesting that there is a potential for escalation. Further, major accidents are complicated by nature and hard to predict. They involve a complex risk picture, multi-linear chain of events, failure in several safety features, and with a potential for uncontrolled escalation.

Accidents related to ship damage stability have been shown to be a major risk contributor for passenger ships through the joint industry project Risk Acceptance Criteria and Risk-Based Damage Stability (DNV GL) and the Goal-Based Damage Stability project (GOALDS) (SLF 55/INF.9, 2012) where annual accident frequencies for passenger ships were determined based on the IHS Fairplay. To increase the accuracy, the data was filtered according to several criteria and the following accident categories were selected for analysis: Collision, contact, grounding, (also designated wrecked/stranded) and fire/explosion (Fig. 1).

Explanation to figure:

1. CN: Collision
2. CT: Contact
3. GR: Grounding (incl. wrecked/stranded)
4. FX: Fire/explosion

The accident frequency statistics show that the main risk contributors for cruise ships are stability related. From 2000 to 2012, there were a total of 59 cruise ship casualties related to grounding, contact and collision and 21 to fire.

The events in the accident statistics are all initial events considered to be serious, and could lead to a major accident with significant loss of life. For major accidents such as capsizing or sinking the risk is uncertain – we are still dependent on our perceptions to determine the risk. Exposure to some risk is unavoidable when operating a large passenger vessel in a seaway and it is not feasible for the industry to contemplate building and operating risk-free ships. The alternative would be a passenger ship never leaving port. The purpose of managing major accident risks is therefore not to eliminate the risk itself but to understand and control it so that risk can be managed in the most effective way.

2. Introduction to barrier management

The purpose of the barrier management approach to safety is to take into account the low frequency and high consequence major accidents by addressing the complexity of these scenarios. If a risk analysis predicts a major accident to occur once in a hundred years, it is hard to tell whether this happens tomorrow, in fifty years or in a hundred. Consequently, management of major accident risk requires good systems, which captures this complexity and reduces uncertainty. This is the main objective, or rationale, behind barrier management (Øie et al., 2014).

E-mail addresses: tobias.king@dnvgl.com (T. King), cvanwelter@rccl.com (C. Van Welter), tor.e.svensen@dnvgl.com (T.E. Svensen).

http://dx.doi.org/10.1016/j.oceaneng.2016.06.049

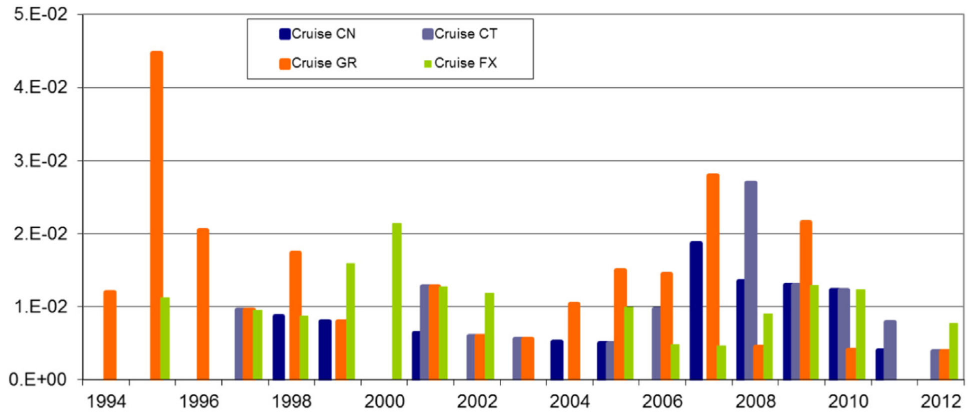

Fig. 1. Annual accident frequencies for passenger ships (excluding ropax) (DNV GL; SLF 55/INF.9, 2012).

2.1. Bowties – the foundation for barrier management

A common way to illustrate barriers is by James Reason's Swiss Cheese Model (Reason, 1997) (Fig. 2):

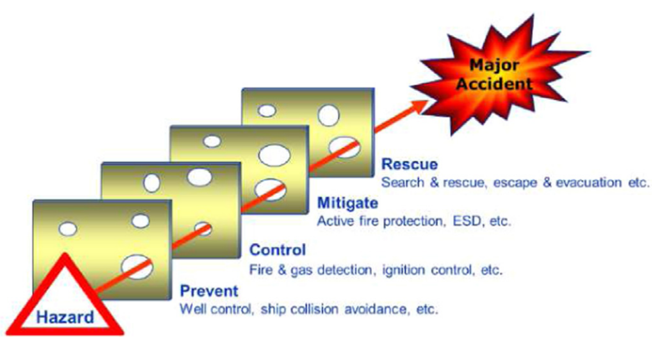

Fig. 2. Swiss cheese model (Reason, 1997).

As revealed by its name, the Swiss Cheese model illustrates an event sequence in which barriers are presented as cheese slices. The holes in the cheese slices represent barrier failure. Throughout the lifetime of a ship, holes in this model are expected to constantly move and change sizes depending on a multitude of causes, such as type of operation, condition of the ship, crew competence, to name but a few. For a major accident to happen, holes in the Swiss Cheese Model need to align, allowing for an accident trajectory.

Safety barriers are defined by making bowties, as has been defined by DNV GL and the Norwegian Ship owner's Association (Øie et al., 2014) to consist of the following elements:

1. Hazard/Threat: Potential for human injury, damage to the environment, damage to property, or a combination of these (ISO 13702).
2. Hazardous event: Incident which occurs when a hazard is realised (NORSOK Z-013; ISO 13702).
3. Barriers: Barriers refer to measures established with an explicit purpose to (1) prevent a hazard from being realised, or (2) to mitigate the effects of a hazardous event.

A simplified presentation of the elements in the bowtie diagram is as follows (Fig. 3):

An example for stability could be a ship sailing in a busy waterway in heavy fog (threat) leading to collision (hazardous event) that may lead, in turn, directly to loss of life (consequences).

The bowtie tool is flexible and standards vary between different companies depending on their needs and what the bowtie structure is used for. As an example, bowties for accident analysis

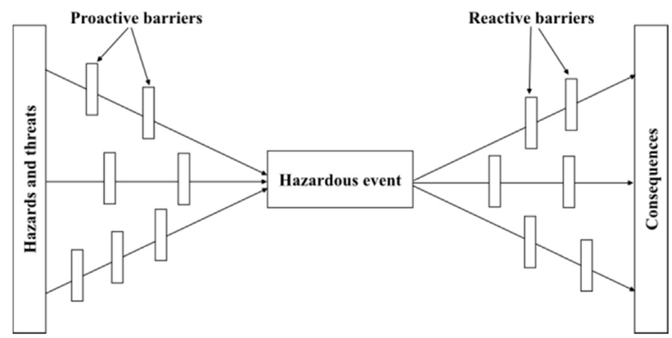

Fig. 3. Simplified bowtie diagram (Astrup et al., 2015).

may differ from bowties used to define barriers in a safety management system or bowties used for the purpose of regulatory development. DNV GL typically uses major accidents as defined in Chapter 1 as hazardous events in the center of the bowties (Øie et al., 2014). Examples of such hazardous events are fire/explosion, capsizing, collision/grounding, loss of power generation, loss of propulsion /maneuvering, terrorism and pollution to air/sea.

These hazardous events are selected to best capture the complexity of major accidents. The bowties are naturally interlinked, meaning that the same incident may be a hazardous event, consequence or a threat depending on how the operator decides to set up the bowtie. Likewise, the same incident may be a threat in one bowtie, and a consequence in another. As an example, a collision may lead to fire/explosion, capsizing, loss of power generation or pollution to sea. Likewise loss of power generation may lead to collision.

From a safety management perspective, the purpose of the bowtie is to define barriers that are the foundation of the management system.

The only way to control a major accident risk is by controlling the integrity of the barriers at all times. By spotting degradation of a barrier at an early stage, one can take necessary action before an accident trajectory opens in the Swiss cheese model. Further, there is a need to have a process in place that continuously analyzes the barriers for improvement potential, either by strengthening the existing barriers or adding new ones.

Using the bowtie structure as a basis for barrier management also contributes to the understanding of major accident risk. If one understands the bowtie, one will also improve the understanding of the complexity of accident risk and the purpose of the different safety functions. For every item that is sorted and managed under a barrier, be it e.g., a job in a maintenance system, a procedure or a rule, the function and purpose of the item is self-explanatory - the bow-tie structure explains *why* the item is there. Likewise, the bowtie structure explains *how* we manage our barriers. A certain barrier is