Lifeboat Evacuation Simulation for Vessels

Helge Soma

Safetec Nordic AS, Claude Monets Allé 5, N-1338 Sandvika, Norway
E-mail: hs@safetec.no

KEYWORDS:

Lifeboat Evacuation, Simulation, Probabilistic Analysis, Risk Assessment.

ABSTRACT

Several disasters with passenger ships in the last years have demonstrated a need for safety improvement. Risk assessment, including evacuation analyses, are promising tools in this respect. This paper starts with a broad overview of possible failures with different types of lifeboats. Thereafter, focus is put on the computer program LBL for simulation of evacuation of passenger ships by conventional lifeboats. LBL was developed several years ago, primarily for simulating evacuation of offshore installations. In the EU project MEP Design, measures for improving evacuation of passenger ships have been analysed, and the LBL program was further developed to assess risks relating to lifeboat evacuation. The LBL program has the potential for significant safety enhancement of passenger ship evacuation.

BACKGROUND

Lifeboats constitute the primary evacuation system on most ships and offshore installations. At present, most lifeboats are totally enclosed. There are two main types of lifeboats, davit launched and free fall. These may further be subdivided in types as shown in the below table.

Table 1 Main Lifeboat Types

	Subtypes	Explanation
Davit Launched	Capsules	One hook – Free rotating during descent
	Off Load Release	Slack fallwires required to release the boat
	On Load Release	Hydrostatic Lock- release with tight fallwires on sea
Free Fall	Slide Launched	Gains horizontal speed away from installation prior to fall
	Vertical drop	Dropped vertically

Difficulties in launching conventional lifeboats in severe weather have been experienced in many accidents. Several lifeboats have collided with the installation during descent, or they have been swept back by large waves and collided with the installation. Release of the boat have also failed in several cases.

The accident with the Alexander L. Kielland platform in 1980 highlighted the limitations with conventional lifeboat evacuation from a listing installation in severe weather. None of the 7 lifeboats were successfully launched, mainly due to problems with the off load release system. In the Norwegian offshore industry, this accident initiated a development towards free fall lifeboats. However, this trend is not followed by most other nations. In shipping, free fall lifeboats are exceptions. One reason for this is that floating installations may list due to flooding, and such events complicate use of free fall boats. However, there is also a large amount of conservatism involved in the maritime legislation. In the Offshore Industry, several semisubmersibles and ship shaped installations are equipped with free fall lifeboats.

LEGISLATION REGIME

For "fixed" offshore installations on the Norwegian Continental Shelf, the NPD requires operators of fields to take the full responsibility and to perform risk assessments. The NPD probably goes further than any other authority in applying risk assessment as a design measure. They require operators to establish their Risk Acceptance Criteria, and they performs audits to verify the operator has systems, qualified personnel on place and that they perform risk assessment according to recognised principles and that the results of the assessments are implemented in the design. It is very difficult to get NPD acceptance for not installing free fall lifeboats on offshore installations.

With respect to the maritime legislation, the situation is different. The basis for this regime is international co-operation through the International Maritime Organisation (IMO) with specific safety requirements on a detailed level, in combination with approvals from national authorities.

However, already in 1969 IMO issued probabilistic damage stability regulations (Resolution A265) for passenger vessels. The consequence calculations were based on statistics form collisions. The probabilities of damaging different bulkheads were calculated as well as the probability of the ship to survive different collision cases. The required probability of keeping the ship afloat for sufficient time for evacuation to be accomplished, given that a collision had occurred, formed the acceptance criterion. These regulations would have formed a logic and sound basis for probabilistic egress and evacuation analyses. Unfortunately the ship owners did not choose to apply the regulation, which was an equivalent alternative to the specific regulation. Hence, IMO and the national authorities lost their position as a driving force with respect to "realistic" risk assessments as basis for design, and left the risk assessment scene to the nuclear, petroleum and offshore industry.

The present maritime legislation regime is based on detailed requirement, approvals and inspections from authorities and the practice leaves the ship owner in a passive position from whom involvement and creativity in deciding on safety measures is not expected. The regime suffers from similar deficiencies as those strongly criticised in the UK investigation following the severe accident with the oil platform Piper Alpha. The response was the Safety Case Regime and Goal Setting Requirements.

If passenger vessels had been treated in a similar way as offshore installations, the ship owner would be responsible for identifying and evaluating all potential accidents, and demonstrate the efficiency of the safety measures implemented to prevent and mitigate the accidents.

Work is ongoing in IMO, which may imply a step in the above direction. IMO may develop regulations based on Risk Assessments, but not directly apply risk assessments in the design process of a ship in a similar way as the NPD requires. Ship owners may be required to demonstrate that evacuation can be performed within a certain time limit (1 hour). However, this limit will be a specific requirement, and not be based upon an analysis of accidents that may occur. Further, reliability requirements with respect to evacuation means may not be stated, despite the fact that potential failure and accident with lifeboats, slides and chutes is a highly recognised problem. Anyhow, the process goes in the right direction, and IMO has recognised that evacuation computer simulations may improve safety, and work is ongoing with specification of the requirements for such computer tools.

EXPERIENCE WITH LIFEBOAT EVACUATION ANALYSES

The Norwegian Consulting Company Quasar has through a 15 year period developed computer programs for evacuation simulations, and performed evacuation studies of about 30 installations and buildings. The ownership of the programs has now been transferred to the Norwegian consultant company Safetec, while Quasar and Safetec co-operates in program development and projects. Few companies, if any, may show a comparable reference record with respect to evacuation analyses.

In order to highlight the development trend in the offshore industry and to compare it with the ship industry, the main development projects and evacuation studies of installations and ships are referred in the below table.

Safetec/Quasar Evacuation Reference List

Table 2. Main Evacuation Simulation Program Development Projects

Time Period	Description of Project	Clients
1997-2001	Updating of LBL to simulate launch of lifeboats from passenger ships, to make the program more general and to improve the User Interface.	EU Commission
1990	Development of a free fall lifeboat simulation program.	Phillips Petroleum.
1990	Inclusion of PROD support in the LBL program.	Phillips Petroleum.
1988	Further development of LBL.	Esso Norge, NFR
1986	Development of the LBL program,	Esso Norge, NFR

Table 3. Main Experience with Evacuation Analyses.

Time Period	Description of Analyses	Clients
1982-2001	Evacuation analyses of several of the North Sea platforms as part of the QRA. Focus is given to availability and reliability of evacuation means. Normally Fault Tree Analyses or Event Tree Analyses are performed. Simulations are usually not performed. (Safetec Analyses)	All main Oil Companies in the Norwegian Continental Shelf
1990-2001	Detailed Emergency Preparedness Analyses of several North Sea Installations, addressing all technical and operational aspects of evacuation. (Safetec)	All main Oil Companies in the Norwegian Continental Shelf
1995	Escape and Evacuation analysis of Statfjord A. (Evacsim, LBL and Offshore Rescue Simulations)	Statoil
1992	Evacuation and Escape Analysis of the ALBA FSU	Chevron UK
1992	Evaluation and Verification of Free Fall Lifeboat Evacuation of three Production Ship concepts evaluated for the Smørbukk Sør Field (LBL Free Fall program)	Statoil

1991	Lifeboat Evacuation Analyses of Brae A and Brae B (LBL)	Marathon Oil UK Limited
1991, 1994	Lifeboat evacuation simulations of the SKJOLD Production Platform (LBL)	Mærsk Olie & Gas (Denmark)
1990-1995	Evacuation Studies of the Heidrun TLP. Free Fall Lifeboat Launch simulations. (Evacsim and LBL)	Conoco Norway Inc.
1990	Success rate comparison betweeen free fall lifeboats and conventional lifeboats with additional equipment like PROD, Bowthrusters, etc (LBL)	Phillips Petroleum
1989	Safety Evaluation of Lifeboat Evacuation at the Ekofisk Field (LBL)	Phillips Petroleum

EVACUATION OF PASSENGER SHIPS

The evacuation process of a passenger vessel may be divided into the following phases: Mustering, Embarkation and Evacuation.

When the captain has decided to muster the passengers, the alarm will be activated and PA announcements will inform passengers and crew about the situation. The passengers are assumed to leave their cabins and walk along the marked escapeways to their muster areas, where the crew will support them in donning their life wests. If the situation deteriorates, embarkation of the lifeboats, which in the meantime have been swung out, will be started. The lifeboats will normally be sequentially launched.

PROBLEM AREAS

The installation to be evacuated may be fixed or floating. Hence, an evacuation scenario may involve list of floating installations, and such scenarios may introduce several problems. It is usual to design evacuation system on floaters for a certain list, usually corresponding to the design damage condition.

There are some failures that are common to all types of lifeboats as referred in the below table.

Table 4 Failure modes common for all lifeboat types

	Comments and possible Consequences
The lifeboat may be swept away by green water prior to evacuation.	In high waves and possibly with reduced hight above sea due to list, green water impact may sweep the boat away before embarkation.
The lifeboat may not be ready for use	A varying degree of preparation is required. All boats are normally secured from inadvertent release. For conventional boats, the davit must be swung out by gravity prior to embarkation.
The engine may fail to start	In launches on windward side, engine power is required to propel the boat away to prevent it from colliding with the installation
A boat may collide with	A collision with a previously launched boat is

previously launched boats or other obstructions	likely to be disastrous. Different procedures are followed to avoid this from happening.
Recover of evacuees in the boat	The boat may reach sheltered water. Otherwise, helicopter or other vessels must recover the evacuees in open seas. This is a risky operation.

The following failures may occur during lifeboat evacuation. Most of the failure modes are related to severe weather.

Table 5 Failure Modes for specific lifeboat types.

	Failure Modes	Possible consequences
Conventional Lifeboats	Premature release high above the sea	A free fall from high above the sea will cause fatalities and severe injuries.
	Collision with installation during descent	The boat may be damaged. The evacuees may be injured from the acceleration loads, in particular if seat-belts are not properly used
	Rotation during descent	The wire for lowering control may be clamped in between fallwires. The helmsman may also loose his orientation.
	Severe slamming at wave impact	The boat may be damaged. The evacuees may be injured from the acceleration loads, in particular if seat-belts are not properly used
	Technical failure to release fallwires	In this event the boat may repeatedly collide and it may start rotating. If only one wire is released, the boat may be hanging vertically in the other one.
	Human Error to release fallwires.	Due to violent motions from wave impact and possible collision, the person responsible for turning the release handle may fall and loose the handle.
	Breakage of one fallwire	If the boat is snatched out of water by tightened fallwires, on its way down behind a crest, the shock load may cause breakage of a fallwire.
	Collisions with installation when on sea	This is a very critical failure mode in launches on the windward side. In severe weather, a single wave may sweep the boat 10-20 meter back, towards the installation.
	Manoeuvring failure	In darkness, with seawater spray, the helmsman may be confused with escape direction are calculated.
Slide Launched Free Fall	Failure to release	There is a small probability (<1%) that the hydraulic system normally used may fail.
	Over-rotation	The lifeboat will start rotating when runners pass the slide end. If the slide slope is low due to ship list, or if the boat hits a wave hollow, over-rotation may occur. In this event the boat may not gain sufficient speed away from the installation.

	Under-rotation	If the boat is released close to a wave crest or hit a wave unfortunately, it may impact the sea with too low keel angle. This may cause excessive accelerations.
Vertical Drop	Failure to release	There is a small probability (<1%) that the hydraulic system normally used may fail.

THE MEP DESIGN PROJECT

Seven European companies with different expertise decided to co-operate in improving the evacuation safety by resolving passenger ship evacuation problems . They agreed on a project plan in 1997, and applied from support from the EU commission. The support was granted from the *Industrial and Materials Technological Research and Technological Development program.* Hence, in 1997 the EU project *Mustering and Evacuation of Passengers: Scientific Basis for Design (MEPdesign)* was launched.

The project will be finished in 2001. The main objectives of the project are to improve the evacuation process of passenger ships and to provide computer models with adequate data bases. The most relevant studies with respect to development of a computer program for lifeboat evacuation simulation, are shortly described in the following. Note that the views expressed in this paper, represents the view of the author and not of the MEP Design consortium.

TNO (Netherlands) is the project leader of MEP Design. In the project, they focused on passenger performance during mustering.

DMI and Scandlines (Denmark) were responsible for the practical studies. The passenger vessel Kronprins Fredrik was used as basis for the evacuation studies.

KTH (Sweden) performed comprehensive model tests with launching of lifeboats and with a slide evacuation system. A particular free fall system was also investigated. Kronprins Fredrik was chosen as mother vessel, and a simplified model, with the same motion characteristics, was developed and used for lifeboat launch tests in a model basin.
Launches of a lifeboat, both from the windward and downwind sides, were tested in 1, 2 and 3 m. high regular waves. The ship was oriented broadside the oncoming waves. The impact on the collision probability from varying initial clearances between the lifeboat and the ship side and different launching speeds were investigated. Accelerations in collisions with the ship side was measured, and the likelihood of the “open” lifeboat to be flooded or to capsize when it become seaborne was assessed. The tests showed a high likelihood of failures in 3 metres, and even in 2 metres wave heights.
Tests performed with a slide system showed also this system to be prone to failures.

DNV is responsible for evaluating the pragmatic value of the project. IFN (Institut Francais de Navigation) performs QA. Quasar/Safetec develop computer programs.

THE LIFEBOAT LAUNCHING (LBL) PROGRAM

The computer program LBL was developed several years ago for simulation of launching of conventional lifeboats from offshore installations.

In the MEP design project, the program has been updated to be more suitable for simulating launch of a lifeboat from a ship exposed to waves. Further, the simulations are visualised by a powerful 3D graphical package.

Offshore installations often consist of trusses, bracings and columns, which only to a limited degree effects the oncoming waves. Hence, it is reasonable to assume that the waves are not affected by the installation. For ships, however, shorter waves are reflected from the ship hull, and very steep waves may result. On the other hand, the horizontal motion of wave particles are restricted by the ship side, and this is favourable as compared to offshore installations. It has so far not been possible to include wave reflection by the ship side in the LBL simulations, and the accuracy is therefore lower then for offshore installations.

In LBL for ship evacuation, both the lifeboat and the ship hull are described by defining points on frames in the same way as in stability calculation programs.

The objective of LBL is to simulate the launch of lifeboats from a ship exposed to waves. The main results are the collision probability and collision speed distribution. Further, slamming loads and effects of possible release delay are calculated.

The program is based on theoretical models of the physical phenomena involved. Regular waves as well as stochastic sea states based on Jonswap or Newman energy spectra are included. The wind model is also based upon a stochastic Davenport energy spectrum. The waves are unidirectional, and the ship can be oriented at any heading. The ship response is calculated based on Response Amplitude Operator (RAO) data for the ship.

The main assumption in LBL is that the launching is initiated at random time in relation to waves and ship motion. This reasonable assumption makes the model probabilistic.

The motion of the fallwire suspension points are calculated based on the ship motion. The pendulum motion of the lifeboat during descent is calculated based on the impact of the moving suspension points, wind gusts and collisions with the ship side.

The lifeboat may be assumed to be immediately released from the fallwires when it is freely floating, or alternatively the time required for release of the lifeboat may be assessed based on a probability distribution. In this case it is possible that the boat may be snatched out of the sea again when a wave passes and the boat moves down behind the crest. This event may cause breakage of a fallwire.

As the boat is small as compared to the length of the dominating wave components, the motion of it when seaborne is calculated based on drag forces, thrust, surfing force on sloping wave surface, rudder moment and inertia forces. This implies that focus is put on the horizontal motion of the boat and the possibility that it may be swept back by waves and collide with the ship side. In this event, the collision speed is calculated.

Collisions may damage the lifeboat. However, even without severe damages, the acceleration loads to the poorly protected passengers may cause severe injuries and fatalities.

LBL performs Monte Carlo simulations. As the simulations are relatively fast, it is possible to perform several hundreds of replications overnight. Cumulative probability distributions with respect to collision speed, slamming speed, etc., are then directly produced.

During the development, the different models in LBL have been compared with the results from analytical models on simplified cases. Further, the LBL results have been compared with the results of the model tests at KTH. Due to the probabilistic nature of the launching operation, a stringent comparison was not possible.

The results of the LBL simulations as well as the results from the KTH tests show that launch of lifeboats from passenger vessels is a high risk operation in wave height above 3 metres.

CONCLUSION

There is very strong evidence that evacuation of passenger ships by use of conventional lifeboats is not safe enough.

In the offshore industry, LBL has been used as a design tool for offshore installations. The graphic presentations have proven to be efficient in highlighting and communicating problems. Hence, LBL may correspondingly be used as a design tool for passenger ships as well as a tool for training and education of the crew.

Preferably the program should be further improved, Anyhow, as it may not be feasible to require model tests for each ship, there does not at present exist more accurate design tools.

REFERENCES

1. Ship motions, ship motions for the passenger ferry m/f Kronprins Frederik. BriteEuram project 97-4229 “MEPdesign” WP 1c.DMI.
2. Influence of Waves and Ship Motions on Safe Evacuation of Passenger Ships. KTH
3. Experimental Investigation of “Slide” and “Fall” Evacuation Systems. Brite Euram project 97-4229 “MEPdesign” WP2d. KTH. Olle og Elena
4. Experimental Investigation of Lifeboat/Davit Evacuation System. BriteEuram project 97-4229”MEPdesign” WP2d. KTH.
5. Software Quality Assurance Plan WP3a, Evacuation. BriteEuram project 97-4229 “MEPdesign” WP3a. Quasar.
6. Lifeboat launch LBL, Theoretical bases. Quasar consultants.
7. H. Soma. “Computer Simulation for Optimisation of Offshore Platform Evacuation” OMAE 1995, København.
8. Risk Assessment of Emergency Evacuation from Offshore Installations. Technica, 1983
9. The investigation report “The Alexander L. Kielland Accident”, NOU 1981.