"Study of "Fall" System for Safe Evacuation of Passenger Ships in Rough Weather"

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Abstract

In this paper the problems connected with evacuation of large passenger ships are discussed. Evacuation of passenger ships by use of conventional systems under realistic weather conditions and ship motions is a very dangerous process. Therefore the conventional systems have been scarcely tested at sea. Previous model tests of the lifeboat system and the "slide" system showed that these systems can be dangerous to use for evacuation of passengers already in 2-3 meter waves. The "fall" system concept for evacuation of passenger ships has been based on improvements suggested as results of the experimental investigation of the conventional lifeboat/davit system. The "fall" system was tested in conditions when the risk connected with evacuation by the lifeboat system was highest. The estimation of the risk was based on measured results, video recordings and assumptions about human tolerance. Tests show that evacuation by the "fall" system will be considerably safer.

Introduction

The goal at ship design is that the ship should never be evacuated at sea as results of damage or fire. Even so sometimes a chain of unlucky circumstances turns the ship into an unsafe situation and the ship has to be evacuated at sea. Then it must be possible for passengers and crew to safely leave the damaged ship also in a fairly harsh environment. According to safety regulations (Ref. [1] and [2]) all passenger ships as well as commercial ships should have a functioning evacuation system.

Accidents with “Herald of Free Enterprise” (1987), “Scandinavian Star” (1990), “Estonia” (1994) and “Sleipner” (1996) show that the safety of many passenger ships today is insufficient and improvement the evacuation systems is an urgent problem. The accidents focused on questions about evacuation of passengers and international and national regulations have been stricter. For example, an evacuation analysis (Ref. [3]) is required since 1999 for all passenger ships at design phase. Unfortunately this analysis mainly focus on the assembly phase and little attention is paid to the abandon ship phase.

On ferries and large passenger ships it is difficult and dangerous to test evacuation systems at sea under realistic environment. Therefore the authorities are satisfied with simple functional harbour tests. Concrete and documented experiences of passenger evacuation at realistic weather conditions are therefore uncommon. For that reason today the requirements for functionality of evacuation systems in rough weather are insufficiently formulated. They are difficult to compare with concrete properties such as capacity and cost of these systems. Therefore conventional evacuation systems for passenger ship are mostly optimised for concrete properties such as low cost and space demands while safety requirements in rough weather conditions in cold water are in general not considered.

Previous investigations of evacuation systems (lifeboats) for offshore structures (Ref. [4] and [5]) and for the large passenger ships (Ref. [6] and [7]) have shown that rough environment and structure’s or ship motions have negative influence on the effectiveness and risks at the evacuation.

Within the “MEP design” project (Ref.[8]) evacuation systems were roughly classified in two types as “capsule” systems and “slide” systems. One standard system of each type was tested in waves and also with a heeled ship. In this investigation attention was given to the study of the overall behaviour of evacuation systems and individual details have been left out. The major task in the present study has been to investigate the interaction between the lifesaving equipment, the ship motions and the waves close to the hull. From the measured behaviour an attempt has also been made to describe the deterioration in effectiveness and risk as a function of wave height and heeling of the ship.

In the present paper a “fall” system concept based on the results of the investigation of the lifeboat system is proposed. Test results of the “fall” system are presented and suggestions for future work put forward.

”Fall” evacuation system

Within the MEPdesign project a third system was proposed as an improvement from model tests carried out by KTH (Ref.[6]). The “fall” system is a compromise between the lifeboat/davit system and the traditional free fall system in order to combine positive features from both systems.

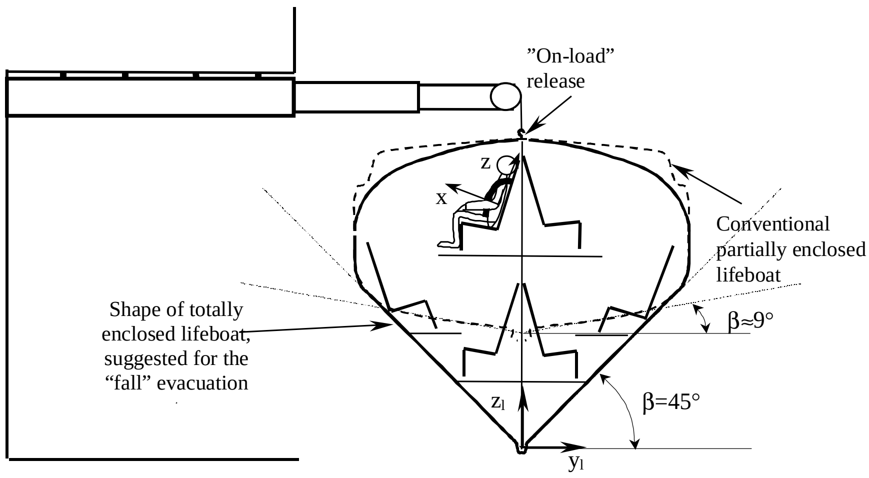


Figure 1. Suggested “fall” system.

The following modifications of the lifeboat/davit system are suggested (Figure 1):

1) Changes of lifeboat design (Similar ideas were presented in Ref. [9]). The lifeboat shape will be changed to reduce the vertical acceleration at the impact against the water (Ref. [10]). Every seat should be designed and constructed to decrease the risk of human injuries at possible impacts against the ship side or the water. The seats should have a neck support and be supplied with a seat belt, which should be used during the descent and disconnection phases in order to decrease the risk of human injuries.

2) Winches with the possibility to increase the lowering speed under severe environmental conditions to damp the lateral lifeboat motions. For the ”fall” system it is suggested that the descent speed can be increased without limit (for the tested cases normally less than 10 m/s). At extreme cases the descent velocity should be high enough to allow the lifeboat to fall freely into the water and the wires should only be kept to prevent the lifeboat from turning over during descent.

3) “On-load” release mechanisms should be improved for quick and safe disconnection. The large number of accidents with “on-load” release mechanisms (Ref. [11]) during lifeboat drills in recent years is due to “unsafe” design of the release mechanisms, improper lifeboat training and incorrect maintenance. In severe wave conditions the water motion in the immediate vicinity of the ship is large and the risk for the lifeboat of capsizing or colliding with the ”mother” ship increases dramatically. A delay in the lifeboat release from the wires in severe weather conditions are very dangerous. It is of importance for safe launching to decrease the disconnection time and the possibility for the lifeboat to sail away from the ship after lowering as quickly as possible.

4) Change in davit construction to increase the length of the davit arm. The davits should be placed as close to water as is practically possible.

5) Direct boarding where the people can embark the lifeboat directly from a protected mustering station.

For the “fall” system the evacuation process will be as follows:

- readying of the lifeboat from stowed to embarkation position
- embarkation
- descent phase including lowering, disconnection and water entry

- sailing away.

The length and beam of the "fall" lifeboat is suggested to be the same as for the conventional lifeboat tested within the MEP project (Ref. [6]), i.e. 11.60 meters and 4.10 meters respectively. There is room for about 120 passengers, with dimensions of seats as for free-fall lifeboats in rules (Ref.[1] and [2]). This means that the capacity of the "fall" lifeboat is about 20% lower than the capacity of the conventional lifeboat.

"Fall" system model

At the scale 1:40 the length of the lifeboat model was 0,29 m and the beam is 0.1 m. In Figure 2 the difference between a shape of a conventional lifeboat and the suggested "fall" lifeboat is presented.

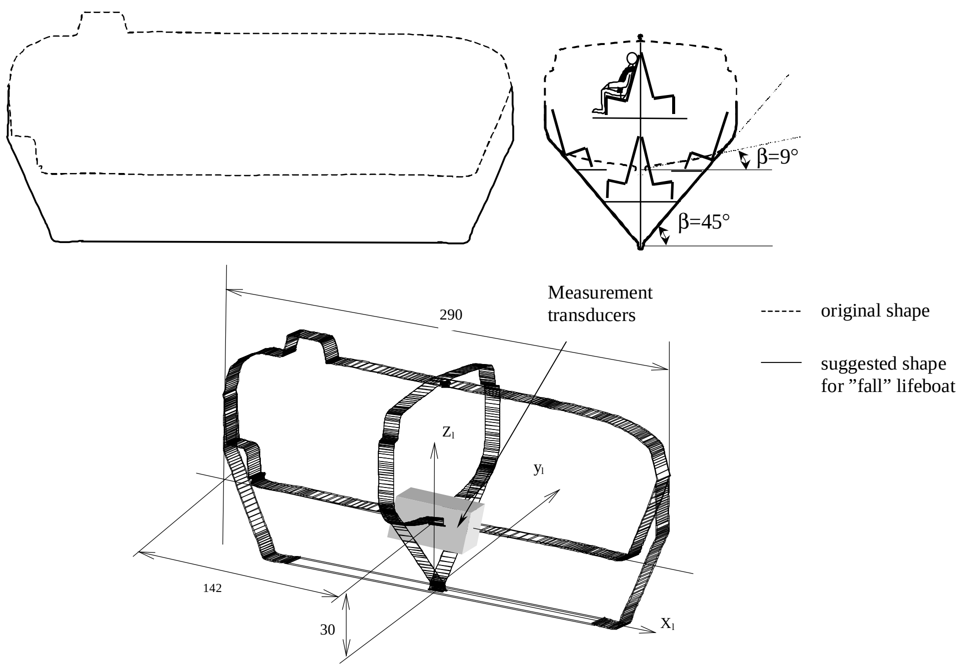


Figure 2. "Fall" lifeboat model.

Transducers for measurements of lateral (y_l-direction) and vertical (z_l-direction) accelerations and the lifeboat model motions were fixed approximately in the centre of gravity of the model. The location of the measurement transducers is shown in Figure 2.The total model weight was about 305 gram, corresponding to a full-scale weight of 19520 kg.

For the "fall" system the same davit model as for the lifeboat system model was used (Ref.[6]).

Evaluation of risk

The evaluation of risk and effectiveness was based on measurements and video recordings. The estimated risk has been classified in three different categories: low, moderate and high risk. In Table 1 the acceptable roll angle and acceleration limits used for estimation of evacuation risk with the "fall" system are presented. The classification was based on acceleration limits for free fall boats (Ref. [2] and [12]), the reference tests of the lifeboat (Ref. [10]) and some assumptions about human tolerance. The research into human injures and behaviour is constantly in progress; when new knowledge is available the estimation of the risk can be re-evaluated.

Table 1. Limits for risk estimation of tests of the "fall" system.

Events connected with risk	Risk level		
	Low	Moderate	High
Acceleration limits. Co-ordinate axis Y [g]	≤ 7	7-10	≥10
Acceleration limits. Co-ordinate axis Z [g]	≤ 7	7-10	≥10
Max roll angle [deg]	≤ 50	≥50	-

It is assumed that the probability of human injures is about 50% for the cases with high risk, 5% for the moderate risk and 0,5% for the low risk cases.

For the roll angle of the lifeboat only two different risk levels are suggested. Moderate risk level means that 5% of passengers will be injured when the maximum roll angle of the lifeboat is about 50 degrees or more. For normal people at the seats and with belts the number of injured should be low.

Results

The aim of the testing was to show that the suggested concept makes it possible to reduce the risks connected with launching of lifeboats. The two most dangerous cases for launching of the lifeboat (Ref.[6]) were launching in longer waves on both sides of the ship and launching in shorter waves on the windward side.

In Figure 3 the motions of the launching point, point of suspension, are illustrated to simplify understanding of further presented diagrams.

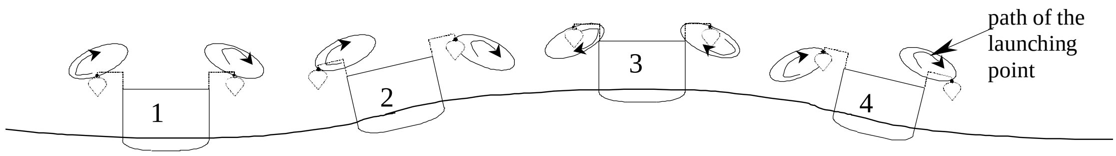
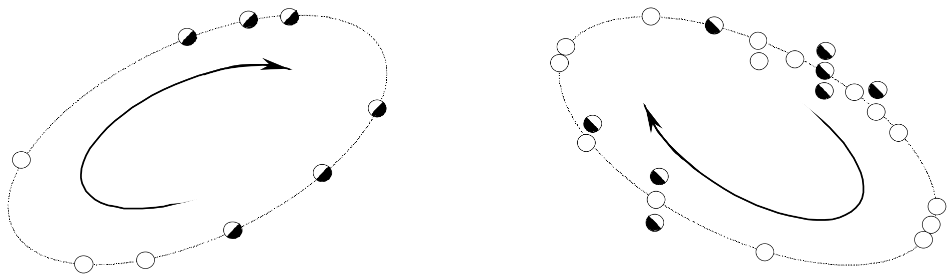


Figure 3. Motions of launching points

In long waves the roll motions of the "mother" ship is large and causes large lateral motions of the lifeboat during descent. This causes impacts against the ship sides. The lowering speed has a damping effect on the lateral motion, i.e. a high speed gives lower lateral motions. During the tests of the "fall" system in waves with a height of 3 meters and a period of 8 seconds the descent speed was varied between 50 to 90% of average free fall velocity. Results of all these tests are presented in Figure 4. Each circle in the diagram represents the risk level for one test. A half filled circle is for moderate risk and a unfilled one for low risk. The davit arm for all tests, presented in Figure 4, is 6 meters and the launching height is 16 meters.



a) b)

Figure 4. Results of "fall" system tests in the longer waves: a) windward side, b) leeward side.

In all tests with a risk level higher than "low" two specific problems are involved. First, if launching starts when the lifeboat is on the way towards the "mother" ship an impact against the "mother" ship can occur. The second problem is that the lifeboat enters the water with a non-zero heeling angle. This occurs if launching starts when the lifeboat is on the way from the "mother" ship when lowering starts. Lateral and angular velocities of the lifeboat have maximum values when the "mother" ship is in position 1 and 3 (Figure 3). If the descent speed is too high the lifeboat continues to move in the lateral direction. However, when the descent speed is lower than the average free fall speed the lifeboat path is adjusted by the action of wires and an impact against the ship side or lifeboat water entry with a non-zero heeling angle can be avoided.

In Figure 5 the same results as in Figure 4b are presented with the tests with the lowering speed higher than 50-55 % of the average free fall velocity are removed. The risk is low for all tests in these conditions.

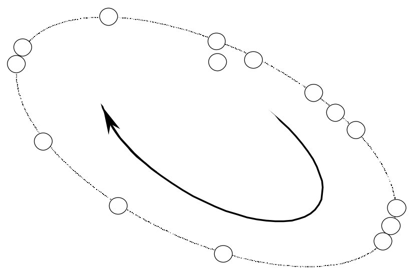


Figure 5. Results on leeward side in the longer waves. Lowering speed is 5.4 m/s.

Some tests with the davit arm of 2,5 meters were carried out. Because the distance between the lifeboat and the ship is smaller it is difficult to avoid impacts if launching starts when the lifeboat is on the way towards the ship.

Some tests were carried out in short waves. Both in the 5 and 6 seconds waves the roll motion of the lifeboat is large after launching. The maximum roll angle is approximately 45 degrees. However, the lifeboat is free in the waves after the water entry (the wires were let go with high speed) and no capsizing occurs.

Further work

Safety work in general has an interdisciplinary character. The technical work has to be combined with the understanding of human aspects. The evacuation process is probably extreme in this respect (Ref.[13] and Ref.[14]). After an accident people under pressure, stress and possibly panic should by guided to behave in a desired manner and operate advanced equipment in a hostile and dangerous environment.

In Figure 6 the structure of the influences between the different groups of problems involved in the evacuation process, is presented. The influence of the environment and the case with the ship heeled to 20 degrees on the technical systems has been modelled in the tests of evacuation systems within the MEP design project. Influence of windward/leeward side of the risk connected with abandon ship process has been also investigated.

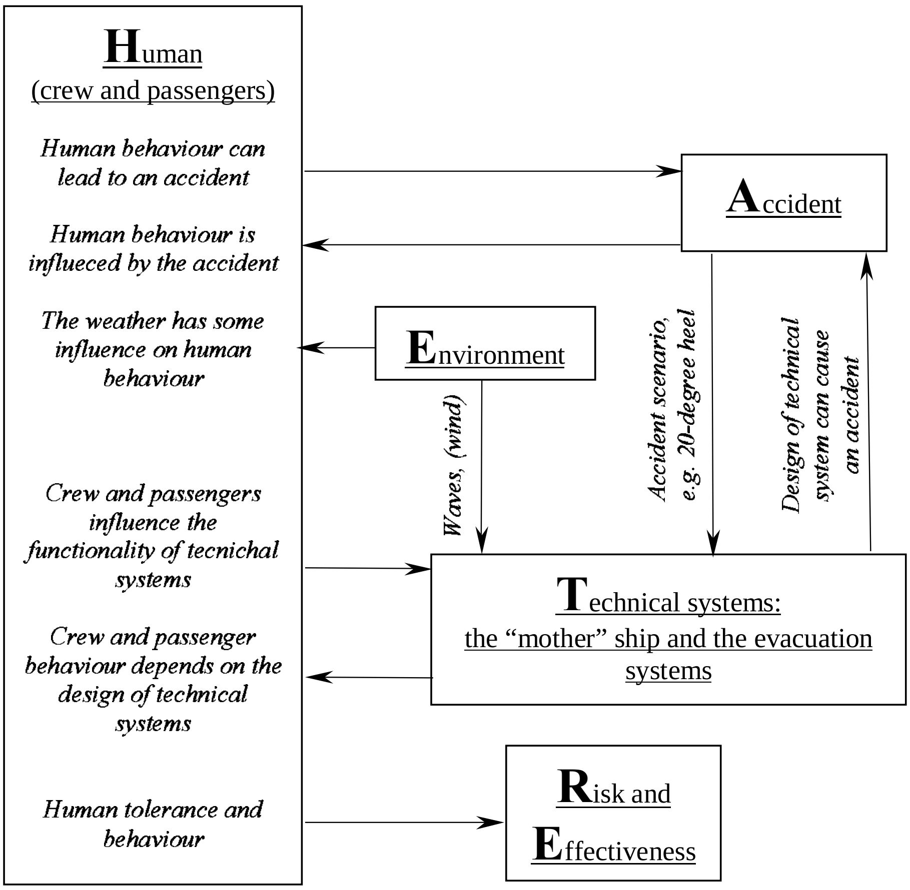


Figure 6. Scheme of influences.

Some assumptions regarding the influence of the technical systems on people and their behaviour are assumed in order to estimate the risk for human injures connected with the evacuation. The risk assessment is based on the measurements and the video recording.

The other relative influences are not studied within this investigation. Thus this work does not cover the influence of installation and maintenance of the life-saving appliances and operational aspects during evacuation.

The aim of the further work is to develop a methodology for a more theoretical approach for statistical estimation of the risk and the effectiveness of abandon ship process for a specific scenario. Such a method will be useful for evaluating both existing and new designs of evacuation systems.

The structure of the methodology is described in Figure 7. The methodology will consist of the following four steps:

- scenario definition
- modelling
- statistical calculation
- presentation of results.

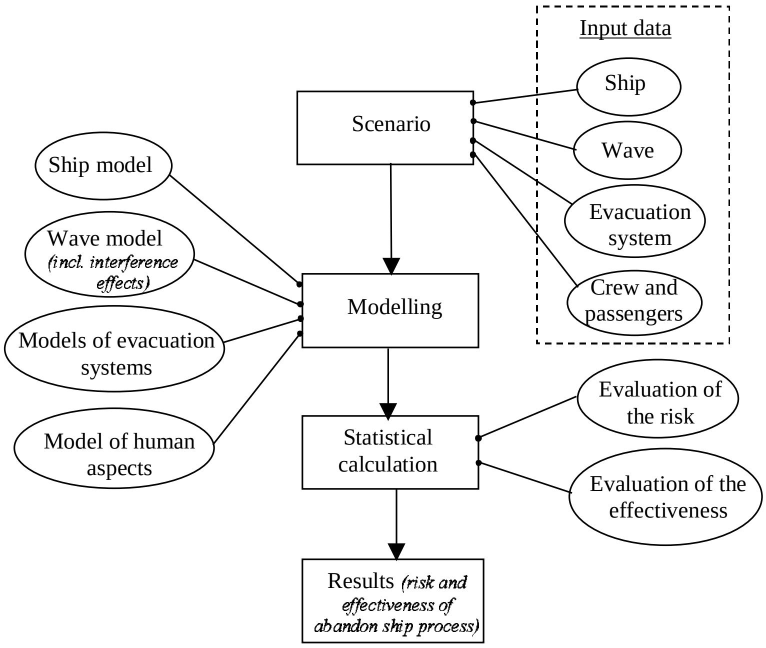


Figure 7. Methodology for the calculation of risk and effectiveness of the abandon ship process.

The scenario will include the input of data and set up of the problem. This input can be divided into four groups, where a number of parameters have to be identified and values stated. The groups are “mother” ship, wave conditions, evacuation systems and characteristics of crew and passengers.

In the modelling phase, models for waves, ship motions, evacuation systems and human aspects will be used in order to calculate the input for the risk and effectiveness evaluation. Waves and ship motions will be simulated in the time-domain. The models of the evacuation systems will have a complex structure and include models for different phases of the abandon ship process for different types of evacuation systems. Models of human aspects will include some experience data for:

- human factors which mean influence of technical systems and environment on human behaviour
- crowd management during abandon ship process
- human tolerance against physical loads.

The statistical models for evaluation of the risk and effectiveness will be used to aggregate the results from the modelling into a total risk and effectiveness of the abandon ship process at the specific scenario.

Discussion and conclusions

The idea of the “fall” system is based on results from tests of a conventional lifeboat system. The “fall” system was tested at wave conditions, in which the risk of evacuation by the lifeboat system was highest. These tests demonstrated that evacuation by the “fall” system is significantly safer than by the lifeboat system.

The evaluation of present experimental results and previous investigation (Ref.[6]) leads to the following conclusions:

- Change of the lifeboat shape allows higher lowering speed and still keeping the vertical acceleration within allowable limits.
- An increase of the lowering speed up to 50-60 % of average free fall velocity decrease the risk.
- An increase of the davit arm has a positive effect on the risk connected with launching.
- A quick disconnection of the lifeboat from the wires decreases the risk for capsizing after water entry.

The following suggestions for development of the “fall” idea are put forward:

- development of the lifeboat shape in order to make it less sensitive to the water entry angle
- more comprehensive design of the lifeboat and boarding arrangements
- elaboration of reliable release mechanisms
- extended study of the influence of the lowering speed should be carried out by simulations.

The aim of future investigation is to develop a methodology for estimating the risk and the effectiveness of abandon ship process. Models for wave presentation, ship motions and evacuation system models should be combined with human behaviour and tolerance models as well as statistical calculations. This method could also be used in the legislation work assessing and improving the safety and efficiency of the evacuation of large passenger ships.

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Authors' biographies

Dr Olle Rutgersson has been a Professor in Naval Architecture at KTH, Stockholm, since 1992. From 1970 to 1992 he worked with SSPA in Gothenburg, where he was involved in the testing and development of naval architectural methods and ship design.

Elena Tsychkova holds a Master degree in Hydrodynamics in 1990 from Shipbuilding University in St Petersburg, Russia and is working towards her doctorate at KTH. She has previously worked as an engineer in the field of mechanics of materials.