"Experimental Investigation of Evacuation Systems on Passenger Ships. - Part II. Slide/Liferaft System"

Elena Tsychkova
Skeppsteknik, KTH, 100 44 Stockholm
elena@fkt.kth.se

Olle Rutgersson
Skeppsteknik, KTH, 100 44 Stockholm
olle@fkt.kth.se

Keywords

Passenger ship, evacuation, slide, life raft, model test.

Abstract

The paper presents results of an experimental investigation of the launching process for a "slide" evacuation system. This investigation has been carried out in order to develop a methodology for testing evacuation appliances in waves, to improve understanding of the evacuation system behaviour, influenced by waves, ship motions and their interference, as well as to obtain data about risk and effectiveness of the system. The present paper is the second part of three presenting results of an investigation of evacuation systems on passenger ferries.

The present work has been focused on the "slide" system including a double-track slide with a boarding platform and life rafts connected to the platform. The "slide" system is launched before embarkation and it stays next to the shipside during the whole embarkation phase. The influence of parameters like wave height and period, heeling angle of the ship, "slide" system parameters and the side of the ship, on which evacuation takes place, was studied. The estimation of the risk involved investigation of possible slide deformations, the slide inclination angle and conditions of the platform and the life rafts. The risk assessment has been based on video recordings. Suggestions for improvement of the "slide" system and the evacuation procedure put forward.

Introduction

In the management of the safety onboard a ship the decision to abandon the ship is one of the last steps to be taken. Only if an accident has happened and a chain of failures, mistakes and unlucky circumstances will turn the ship into an unsafe place, will the abandon ship operation be carried through. When all other safety measures fail, it must be possible for passengers and crew to safely leave a damaged ship even in a fairly harsh environment. The present work deals with problems concerning this last link in the safety chain, namely evacuating the passengers in rough weather.

Studying 131 incidents that took place between 1960 and 1981 with merchant vessels shows the following casualty rates (Ref.[1]):

- 78 % of heavy weather incidents involved loss of lives as a result of attempts to evacuate; for calm/moderate weather this number was 16 %;
- 35 % of all those attempting to evacuate in heavy weather were killed in the attempt, for calm/moderate weather this number was 5 %.

Evacuation systems in use on RoRo ferries and passenger ships are mainly designed and tested for use in calm weather situations with the ship in upright conditions (Ref.[2]). The behaviour of these systems and the deterioration of their effectiveness with increasing wave height and the ship motions are not adequately investigated.

All “slide” systems should be tested according to SOLAS and LSA Code (Ref.[3] and Ref.[4]). These tests include harbour trials under controlled condition to evacuate passengers of various ages and abilities within 30 minutes as well as the functional tests with the ship heeled to 20 degrees. Present regulations include the tests in waves of a new type of “slide” systems, a system with a vertical chute. However, these rules deal only with technical aspects and do not take account of human behaviour and tolerance.

The aim of the present work was to provide a “MEP design” (EU-project “Mustering and Evacuation of Passengers”, Ref.[5] and [6]) computer model with a database of the risks and effectiveness in connection with launching in rough weather and heeled conditions. The work was carried out through an experimental investigation at Division of Naval Architecture (KTH, Stockholm). The study also tried to find new design features to make the evacuation from a moving and heeled ship faster and safer than today.

Within this work all evacuation systems have been 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. This paper includes results of the investigation of the “slide” system. The “lifeboat” system has been discussed in Part I.

In the present investigation attention has been focused on 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 evacuation system, 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. Useful results have been obtained and suggestions for improvements of some design features and evacuation procedures are submitted.

“Slide” evacuation systems

The abandon ship process (Figure 1) for a “slide” system can generally be described in the following five phases:

- readying equipment and passengers for launching;
- descent of evacuation system;
- individual embarkation of passengers;
- disconnection of rescue vehicle from the ”mother” ship;
- sail away of rescue vehicle.

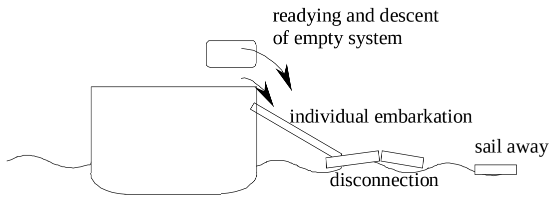


Figure 1. Abandon ship process with “slide” evacuation system.

In the ”slide” system (Figure 1), the capsules (usually life rafts) are launched without people in them. The capsules are then connected to a special transport device (Figure 2) through which people can be moved from the mustering station down to the water level and into the capsule. This group of systems has here been named ”slide” systems after the most common system of this type in use today.

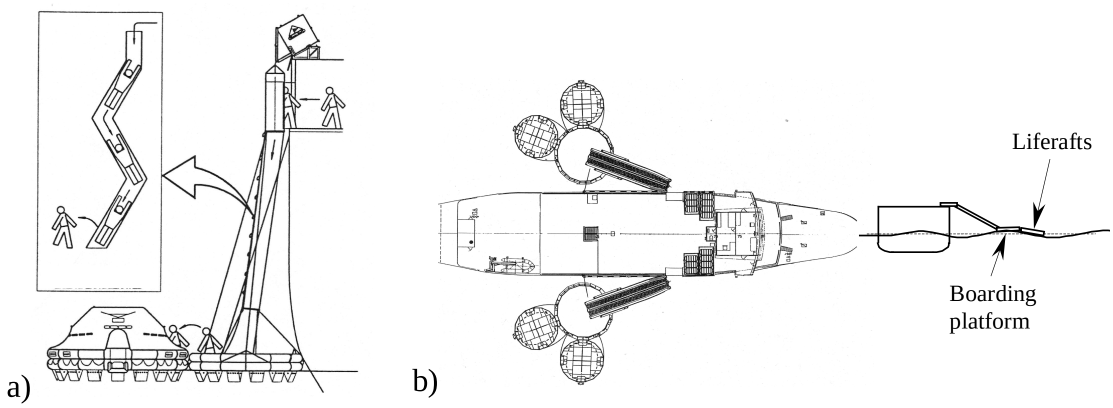


Figure 2. “Slide” systems: a) chute; b) slide.

The main advantages of the ”slide” systems are:
- more space efficient onboard when it is not in use;
- one launching device can be used for many life rafts;
- the demand on the number of skilled seamen for operation is limited;
- as one person at a time is using the slide the risk for serious accidents is low during training and use in calm and warm environment.

The main disadvantages of the ”slide” systems are:
- the exposure to wind, waves and cold weather is large. It is probably not possible to use the system without being exposed to large amounts of seawater.
- may be difficult to use for children, elderly and disabled people;
- the platform / capsule will be exposed to the interaction with waves and the damaged ship during a fairly long time. There are small possibilities to choose ”windows” in the encountering waves with relatively smaller wave heights.

New systems of this type are presented all the time. They all, however, have the principle in common that the platform or capsules are moored along the shipside during the whole evacuation procedure and passengers have to transport themselves through the system to the capsule. In the last few years some systems with vertical chutes (Figure 2, a) have been presented. The chute can be connected to the boarding platform or directly to the life raft. The inside of the chute is designed to keep the speed of the person making descent within a safe level through direct friction with the person's clothes. Also systems of the "zig-zag" type have been proposed.

All systems with the vertical chutes have some disadvantages in common. Firstly, the platform and life raft are in dangerous vicinity of the "mother" ship during the whole evacuation phase. This increases the risk for the platform or the life rafts to be caught on some part of the ship construction and to be pushed under the water. Secondly, in short waves when the wave reflection against the shipside is large, the relative motion between the platform and the ship can be larger than the wave height. The chute length will be strongly varied during a wave period. Another problem with this type of systems is that people may hesitate to enter the chute, especially in rough environment.

"Slide" system models

Description of test facilities, model tests setup and the "mother" ship model has presented in Part I of this paper.

As a prototype for the "slide" system a double track slide with a fixed boarding platform and life rafts was chosen. This system was most widespread on the passenger ferries when this study was started. When evacuating by this system the passengers should help themselves down into the life rafts via the boarding platform. This system has a low manufacturing and operating cost and enables evacuation of a large number of passengers in a short time in still weather conditions (Ref.[7]).

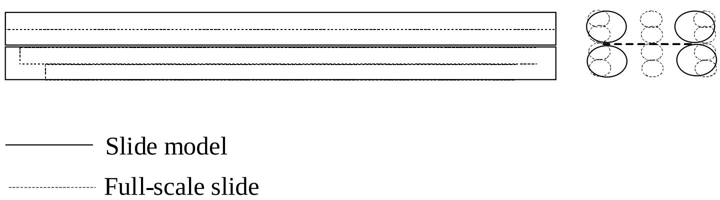


Figure 3. Slide shape.

Four cases of slide parameters were tested. The length of the slide and the angle between the slide and the "mother" ship were varied. The inclination angle between the slide and the still water level was the same for all cases, i.e. 30 degrees. At the scale of 40 the length of the slide model was 625 mm for the 25-meter slide and 375 mm for the 15-meter slide. Both slide models were inflatable and manufactured of light material. The weight of the longer slide model was 6,5 gram, which corresponds to 420 kg in full scale. Due to weight requirements it was impossible to manufacture exact copies of the full-scale slides and some simplifications of the slide shape had to be made (Figure 3).

To the boarding platform the full-scale slide is connected so that it can move about 0.5

meter in the longitudinal axis-direction of the slide (Figure 4). In the proceeding text this connection is called “free”. To the evacuation platform the slide is connected so that it is able to move almost free around the y*-axis and the slide’s stiffness keeps it from rotating about the z*-axis (Figure 4).

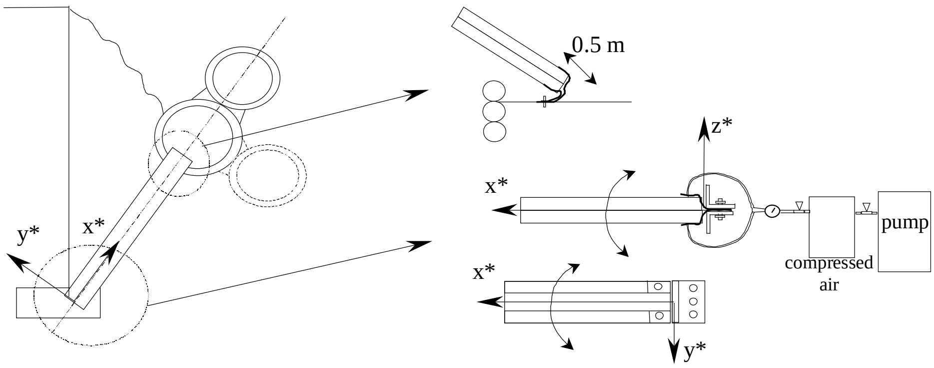


Figure 4. Test setup of the slide system.

During the evacuation tests the slides were tested with both normal and 50% higher than normal pressure. The internal pressure in the slide model was kept on required level by a control system, which consists of a pump, a compressed air reservoir, a pressure-gauge and a drain valve (Figure 4).

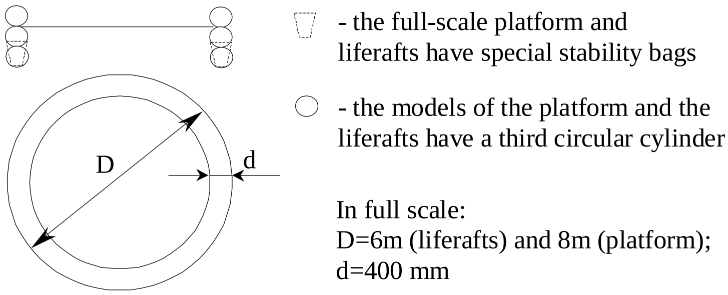


Figure 5. Boarding platform and life rafts.

The boarding platform has a capacity of 100 occupants and the life rafts 50 passengers each. The full-scale platform has a circular form with a diameter of 8 meter. The diameter of the life raft is 6 meters. The full-scale platform and the life rafts were manufactured of two inflatable cylinders (Figure 5) and the floor was made of material, which allows water only in one direction out from the life rafts, but not in. The weight of the full-scale platform is about 450 kg and the life raft weights about 200 kg.

The boarding platform model and the life raft models have the same shape. Instead of inflatable cylinders, cylinders of lightweight cellplast were used for the models. The floor was made of light net material. The weight of the platform and life raft models are 6,6 and 9,3 grams respectively, which corresponds to the weight of the full-scale life raft with 3 occupants and the full-scale platform with 2 passengers on it. In this paper this condition of the platform and life rafts is called “empty”.

The life raft models have a canopy and the platform is open. Except weight and dimensions no other parameters of the platform and life rafts were scaled. Both the platform and life rafts models can be assumed to be rigid.

Evaluation of risk

In the present study the risks connected with the embarkation phase were investigated. This is the phase when the system has already been launched, the slide is moored along the shipside and the passengers should embark the raft by first sliding down to the platform and then climb into the raft. The risks connected with the other phases of the abandon-ship process, such as readying of equipment, descent of system, disconnection and sail away, have been left out. In contrast to the lifeboat/davit system, the slide/life raft system in the embarkation position is exposed to forces both from the incoming and reflected waves and the rolling of the ”mother” ship. The following parameters were taken into account for the risk assessment (see also Table 1):

- deformation of slide axis (temporary buckling)
- maximum roll angle of boarding platform and life rafts;
- steepness of the slide (steep or negative angle);
- boarding platform condition (lift-off from the water or push under the water).

Table 1. Limits for evaluation of tests for the slide system.

Risk factors	Limits of risk levels		
	Low	Moderate	High
Deformation of the slide axis	a) < 1 m or b) 1-2 m occasionally	a) 1-2 m or b) >2 m occasionally	a) > 2 m
Steepness of slide [deg]	max<+45 min>+5	+45 <max< +60 -15<min<+5	max> +60 min < -15
Boarding platform condition (lift-off from water or push under water)	no	< 25% of platform circumference	>25% of platform circumference
Maximum roll angle of the boarding platform and/or life rafts	<20 deg	20-40 deg	>40 deg

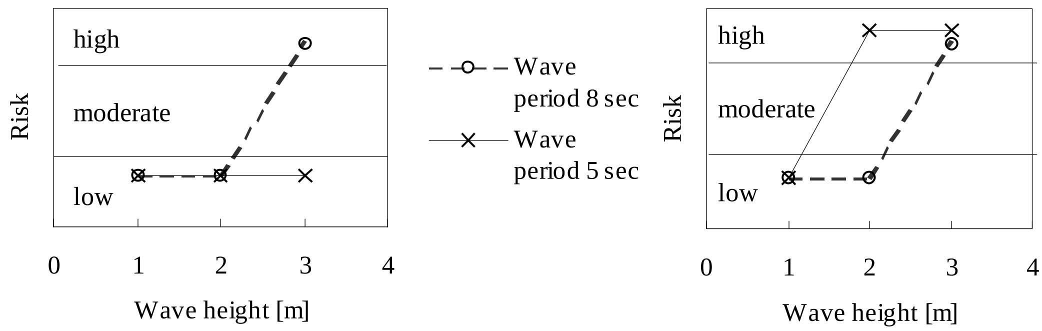
For an individual passenger during embarkation these events can result in falling into the water and injuries, such as breaking legs and arms, during the deformation of the slide or if steepness of the slide is too large.

The risk estimation at each test is based on video recordings. In the same way as for the lifeboat system the low risk corresponds to an estimated probability of injuries of about 0.5%, the moderate about 5% and the high about 50% for an arbitrary person.

Results

The “slide” system is exposed to two dynamic loads (waves and the “mother” ship motions) during the whole embarkation phase. This fact has a strong negative effect on the risk connected with embarkation.

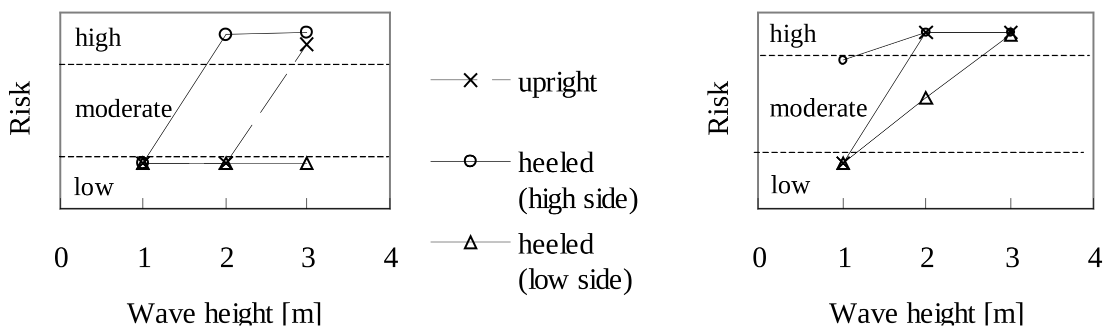
The tested "slide" system fulfils its functions only during gentle weather conditions. At the majority of the tests in 1m waves the risk of launching corresponds to the risk in still weather. With increasing wave height the risk quickly increases (Figure 6).



a) leeward side *b) windward side*

Figure 6. Total risk connected with embarkation of the system with the 25-metres slide in waves.

The wave period influences the risk in different ways on the windward and the leeward side. In long waves the motions of the "mother" ship are large and wave reflections on the ship side are small. Influence of windward/leeward side will be small and the risk connected with evacuation is similar for the both sides (Figure 6, wave with a period of 8 sec). The short waves cause small roll motions of the "mother" ship, they are effectively reflected against the ship side and cause a large difference in wave climate on windward and leeward side of the ship. The influence of windward/leeward side is large due to wave reflections (Figure 6, wave with a period of 5 sec).



a) wave period 8 seconds *b) wave period 5 seconds*

Figure 7. Total risk connected with embarkation by the system with the 25-metres slide (30 degrees angle between the ship and the slide; normal internal pressure) on the windward side in waves.

For most of the tests the risk connected with embarkation increases on the high side and decreases on the low side by comparison to the ship in upright condition (Figure 7). However, during embarkation on the low side the inclination angle of the shorter slide can be negative at occasions when the platform is on a wave crest. Furthermore the evacuation station is located closer to the water surface and can be immersed into the water during evacuation on the low side. This makes embarkation nearly impossible. On the high side the shorter slide can lift the platform up from the water while the inclination angle is about 70 degrees or more.

The influence of the "slide" system parameters is largest in the longer wave. The total weight of passengers on the platform and in the life rafts has a strong effect on the slide deformation and thereby on the risk connected with embarkation. As shown in Figure 8 the risk increases with the number of passengers on the boarding platform and in life rafts.

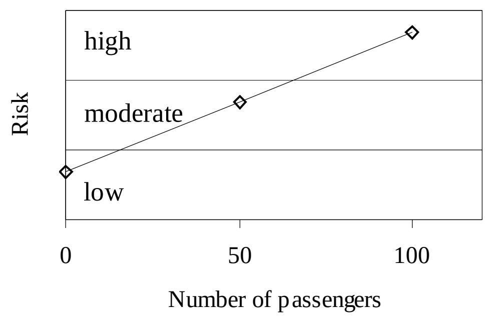


Figure 8. Influence of loading condition on the risk of embarkation of the slide system on windward side in 3-meter waves with a period of 8 seconds.

The slide stiffness depends on the slide length and internal pressure, which were varied during the tests. Increase of the slide stiffness decreases the risk for slide deformation, but leads to other negative effects. When the slide is sufficiently stiff, a situation, where the slide pushes the platform under water, can occur.

Influence of the slide length involves two effects. Firstly, with decrease of the slide length the slide stiffness increases as was discussed above. Secondly, the slide length affects the inclination angle of the slide on a heeled ship. The angle of inclination of the shorter slide at the high side can be too large even in still weather and when the ship roll motion is large it can be impossible to use it. On the low side the inclination angle of the short slide can be negative in waves. Moreover the evacuation station on the ship can be located too close to the water

The risk connected with evacuation is also dependent on the geometry relation between a wave length and a slide length. An explanation for this is pictured in Figure 9. In the case 1 the force, acting on the slide along longitudinal axis, is higher than in the case 2. Shorter slide, which is stiffer than the longer slide, can be deformed before deformation of the longer one occurs.

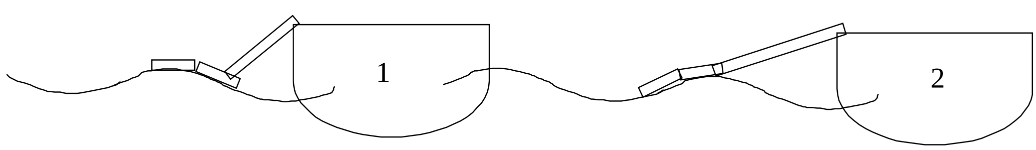


Figure 9. Influence of geometry on the risk connected with evacuation.

The risk for the system with 90 degrees angle between the slide and the shipside is generally higher than for the system where this angle is 30 degrees.

The connection between the slide and the platform, by which a part of relative motion between the ship and the platform is taken over, has a profound positive effect on the intensity of the slide deformations.

The slide system with 30-degree angle between the ship and the 25-meters slide was tested in irregular waves with a significant height of 2 m and a zero down-crossing period of 6 sec. The evacuation was performed on the windward side and with the ship in upright condition. The roll angle of the ship was from 2-3 degrees up to 10 degrees, depending on the incoming wave amplitude. The system was loaded with the weight corresponding to a weight of 50 passengers and internal pressure was normal. The risk depends on the slide deformation and was assumed as moderate according to premises of the risk estimation. The risk is lower than for this system in regular waves, which depends on "windows" in the incoming wave with relatively small wave heights.

Discussion and conclusion

The "slide" system behaviour during embarkation was experimentally investigated. A number of key parameters, such as the ship condition, the launching side, the slide parameters (length, stiffness, angle between the slide and the ship), the load condition (number of passengers on the platform and in the life rafts) and the wave condition, have been studied and their effects on the system behaviour have been investigated. Risk assessment was based on video recordings.

The results led to an improved understanding of the abandon ship operation by the "slide" system. The following conclusions and suggestions for improvement for the conventional "slide" system are put forward:

- The slide in this system has two functions. The first is to keep the life rafts along the shipside and the other is to transport passengers to the life rafts. It is possible that separation of these two functions would have a positive effect on the risk.
- The "slide" system is exposed to two dynamic loads (waves and the "mother" ship motions) during the whole embarkation phase. This fact is based on the system definition and can not be changed. However, this fact has strong negative effect on the risk connected with embarkation.
- Occupants are exposed to the weather during embarkation. The system, where occupants come directly to the life raft or close platform, are more preferable. Covering of the slide can also lead to decrease of the risk.
- The slide length is an important parameter and should receive more attention in design phase.
- Increase of the slide stiffness decreases the risk for slide deformation, but leads to other negative effects. The platform can be pushed under the water by the slide.
- A "free" connection between the slide and the platform has a positive influence on the risk of initiation of slide deformation and it's intensity.
- The total weight of passengers on the platform and in the life rafts has a strong effect

on the slide deformation. During evacuation in hard weather condition, in view of this fact, the crew should not place too many people in each life raft and should not have a lot of passengers on the platform. This recommendation leads to an increase of the number of life rafts onboard or use of smaller rafts. This also requires a well-trained crew.

References

[1] Pyman M.A.F. Lyon P.R., "Casualty Rates in Abandoning Ships at Sea", Joint Meeting of The Royal Institution of Naval Architects and The nautical Institute, January, 1985.

[2] Captain Stephen Taylor, "A System Approach to Escape, Evacuation and Recovery", SASMEX International '98, Paper 6.

[3] "International convention for the SAFETY OF LIFE AT SEA", IMO, London, 2001.

[4] "International Life-Saving Appliance (LSA) Code, 2001.

[5] Olle Rutgersson, Elena Tsychkova, "Safety Management of the Mustering and Evacuation of Damaged Passenger Ships - MEPdesign on The Development of a Tool Box", RINA conference "Learning from Marine Incidents", London, October 1999.

[6] Tsychkova Elena, "Influence of Waves and Ship Motions on Safe Evacuation of Passenger Ships", Licentiate Thesis, Stockholm, 2000.

[7] Jens Peter Bie, "Safety – are we all in the same boat?", SASMEX International '98.

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.