DMAIB
DANISH MARITIME ACCIDENT INVESTIGATION BOARD

DANMARK

Marine accident report on occupational accident

16 FEBRUARY 2022

MARINE ACCIDENT REPORT ON OCCUPATIONAL ACCIDENT ON DANMARK ON FEBRUARY 2022

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Photo: Fore-topgallant mast on DANMARK
Source: DMAIB

The investigations are carried out separately from the criminal investigation, without having used legal evidence procedures and with no other basic aim than learning about accidents with the purpose of gaining and promoting an understanding of safety. Consequently, any use of this report for other purposes may lead to erroneous or misleading interpretations.

Content

Introduction

On 16 February 2022, the Danish Maritime Accident Investigation Board (DMAIB) received notification from the Danish Maritime Authority that a quartermaster from the training vessel DANMARK had fallen from the ship's fore-topgallant mast while the ship was alongside at Assens Shipyard. Later that day, DMAIB was informed that the quartermaster had been pronounced dead at Odense University Hospital.

In view of the very serious consequences of the accident, DMAIB decided to start a preliminary investigation to clarify the course of events and circumstances of the accident. Two accident investigators were deployed to Assens, where the accident site was investigated and documented. In addition, the ship's crew was interviewed.

The course of events identified during the preliminary investigation formed the basis for the later investigation of the circumstances that led to the quartermaster's death.

Narrative

Background

The training ship DANMARK (see appendix and figure 1) was a full-rigged ship with an auxiliary engine and was built at Nakskov Shipyard in 1933.

At the time of the accident, the ship was owned by the Danish Agency for Higher Education and Science, and managed by the MARTEC-Maritime and Polytechnic College in Frederikshavn, Denmark. The ship normally had 15 crew members but also carried up to 80 students participating in a basic maritime course to qualify as ordinary seamen. In addition, the ship was used for various representative purposes in connection with calls at ports in Denmark and abroad.

On 13 February 2022 at 09:00, DANMARK departed Frederikshavn for Assens Shipyard with 12 crew members only. The ship was due to be docked for a regular scheduled overhaul and maintenance on 21 February. The ship was to arrive a few days before, so the crew could prepare the ship for docking, including the dismantling of parts of the rigging. Two days later, the ship arrived in Assens, where three of the crew members left the ship. The remaining nine crew members were to stay on board and assist with the maintenance work before and during the shipyard stay.

Figure 1: DANMARK
Source: Finn Føns

The accident

RECONSTRUCTION OF THE COURSE OF EVENTS

The description of the course of events is based on the testimony of crew members who were positioned in various places on the ship and ashore when the accident occurred. In addition, testimonies and photo footage were obtained from a passing witness who was watching the ship immediately before the accident happened.

The course of events is a summary of the testimonies and covers the period from the time work on the ship began on February 16, 2022 at 8:00 until the quartermaster was pronounced dead at 13:19 on the same day.

All times are indicated in the ship's local time UTC (+1).

On February 16, the day's work started with a morning meeting at 08:00, which the crew discussed the tasks of the day and agreed the division of work. The crew had to dismantle the royal yard and the topgallant yard on all three masts (figure 2) using a mobile crane, which would arrive at the quay at 09:00. It was agreed that the yards were to be brought down to the quay from all three masts working from aft.

Figure 2: Royal yard and topgallant yard on the for-topgallant mast that were to be dismantled.
Source: DMAIB

To complete the task, five quartermasters went aloft two at a time to dismantle the yards and attach strops to which the lifting hook of the mobile crane was attached. On the quay, a mate accompanied he crane operator. The mate was in radio contact with the quartermasters in the masts, so they could alert the mate when the lifting hook was attached and the yard could be lifted away from the mast. The chief mate stood on the forecastle, holding the guide ropes of the yard being lifted off.

The five quartermasters worked in shifts. While the crane was in the process of lifting the yards down from the first mast, the yards on the next mast were prepared. By 1100, the yards had been lowered from the mizzen and main topgallant masts, but the crew had yet to lower the foremast's yards.

The two quartermasters on the foremast had prepared the royal yard but they did not have a radio to communicate with the mate, or strops to attach to the topgallant yard. As a result, a quartermaster who had just climbed down from the main topgallant mast, climbed the port side of the foremast carrying strops and a rigging bag containing a UHF radio. As he climbed, the two quartermasters that were already aloft on the foremast waited, one in the Jacob's ladder over the royal yard, and the other at the royal yard (figure 3).

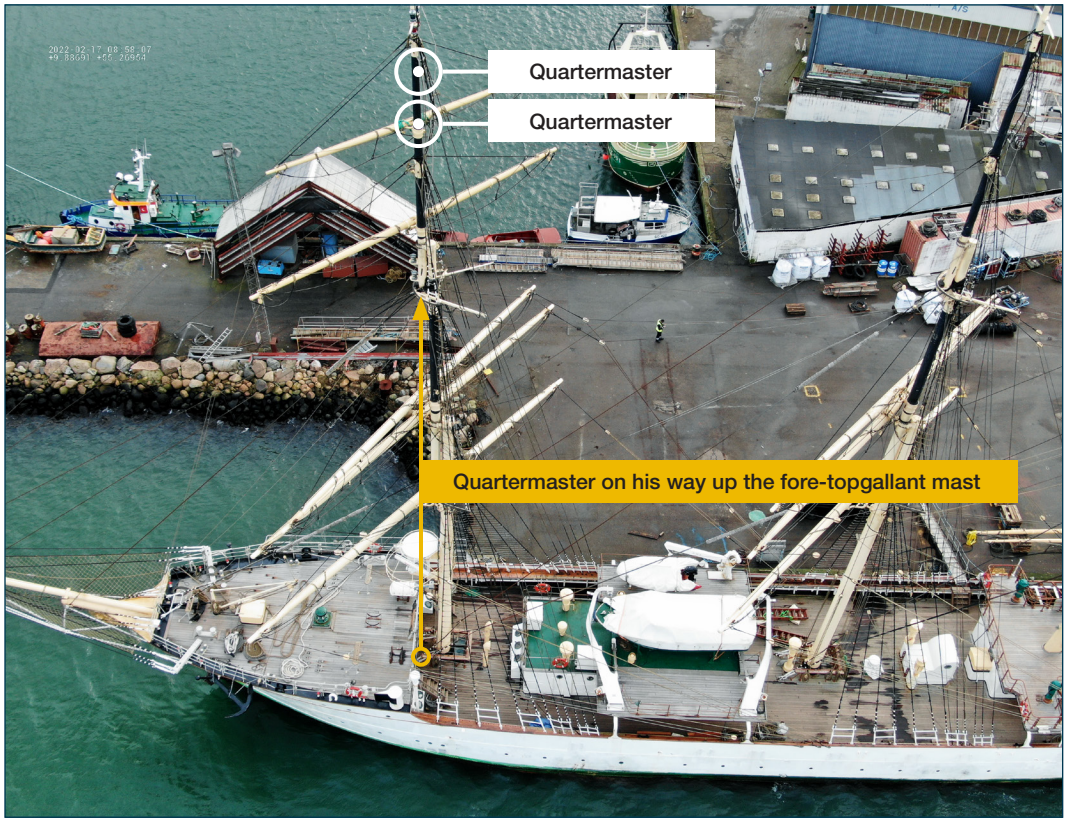

Figure 3: Overview of fore-topgallant mast.
Source: DMAIB

The quartermasters in the foremast watched the quartermaster as he climbed up towards them at an unhurried pace. When he reached the topmast crosstrees, he got hold of the shroud over the topmast crosstrees with both hands. Suddenly, they saw the quartermaster fall.

‘The quartermaster’s fall was also seen by the mate on the quay and the chief mate on the forecastle. The chief mate hurried down to the deck, where he found the quartermaster lying face down by the pin rack. He immediately realised that the quartermaster was in critical condition and started providing first aid while the other crew members gathered around him. He quickly consulted with the other crew members about what to do.

The mate ran down to his cabin, picked up his phone and called emergency services. Another crew member retrieved scissors so they could cut the quartermaster’s fall arrest harness apart and take it off to better treat the injured quartermaster. One of the other quartermasters rushed out to the road to receive the ambulance that was on its way. A few minutes later, the ambulance and a medical car arrived. Rescuers boarded and took over the treatment of the injured quartermaster. After the initial treatment, the injured quartermaster was placed on a stretcher and taken to the ambulance, which took him to Odense University Hospital. Later that day, at 13:19, the quartermaster was pronounced dead.

Investigation

UNDERSØGELSESPROCESSEN

After the reconstruction of the course of events, it became clear that the quartermaster perished as a result of a fall accident from the rigging during routine planned maintenance work.

The investigation of DMAIB thus had two objectives:

- To identify the circumstances of the quartermaster's fall from the rigging, through examination of the scene of the accident and weather conditions, as well as the quartermaster's equipment, clothing and health.
- To identify the barriers that the crew had adopted to avoid falls from the rigging, through examination of the management company's safety management system, the crew's climbing practices in the rigging and legislation and regulatory oversight regarding work at height.

The accident site

The foremast consisted of three parts: foremast, top mast and gallant mast. These were joined at the top and the topmast crosstrees and connected by three steel wire rope shrouds (fore-lower shroud, topmast shroud and topgallant shroud) with ratlines of rope, which afforded access from the deck up to the yards (figure 4). The fore-topgallant mast had five yards: Fore-yard, lower topsail yard, upper topsail yard, topgallant yard and royal yard.

The upper part of the rigging was attached on the underside of the top and the topmast crosstrees. On the underside of the top and the topmast crosstrees, respectively, were a futtockshroud and a topmast futtockshroud of round iron with ratlines of rope mounted to ensure a foothold when climbing from the shroud onto the top or the topmast crosstrees (figure 5). The shrouds were attached at the bottom with a shackle and a rigging screw on the platform made up by the top and the topmast crosstrees, respectively (figure 6).

The topmast crosstrees had an overhang of about 75 cm from the topmast at its widest point, which made it necessary for the quartermaster to climb by way of the topmast futtockshroud to get up and out over the topmast crosstrees (figure 7). Figure 8 shows a picture taken from the spot on the pin rack where the quartermaster fell from the topmast crosstrees. The distance between the topmast crosstrees and the deck was about 25 metres. The quartermaster fell directly onto the pin rack as there was no rigging in that area to break the fall.

DMAIB carried out photo documentation of the standing rigging with camera and drone footage. Reviewing the documentation, no flaws or defects were found on the parts of the standing rigging with which the quartermaster came into contact immediately before the fall from the topmast crosstrees.

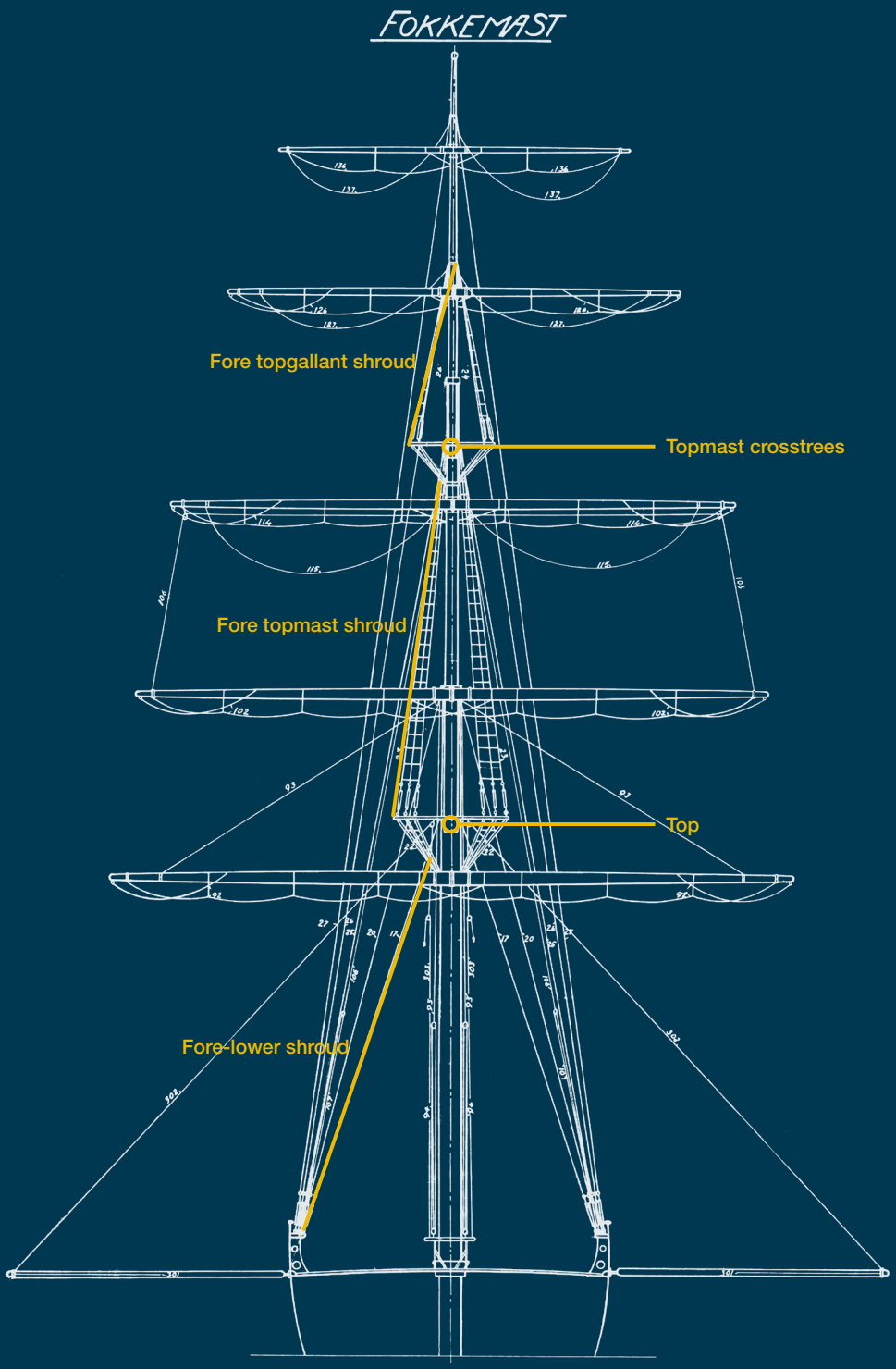

Figure 4: Fore-topgallant mast on DANMARK
Source: Nakskov Shipyard/DANMARK, modified by DMAIB

Figure 5: The underside of the top in the fore-topgallant mast.
Source: DMAIB

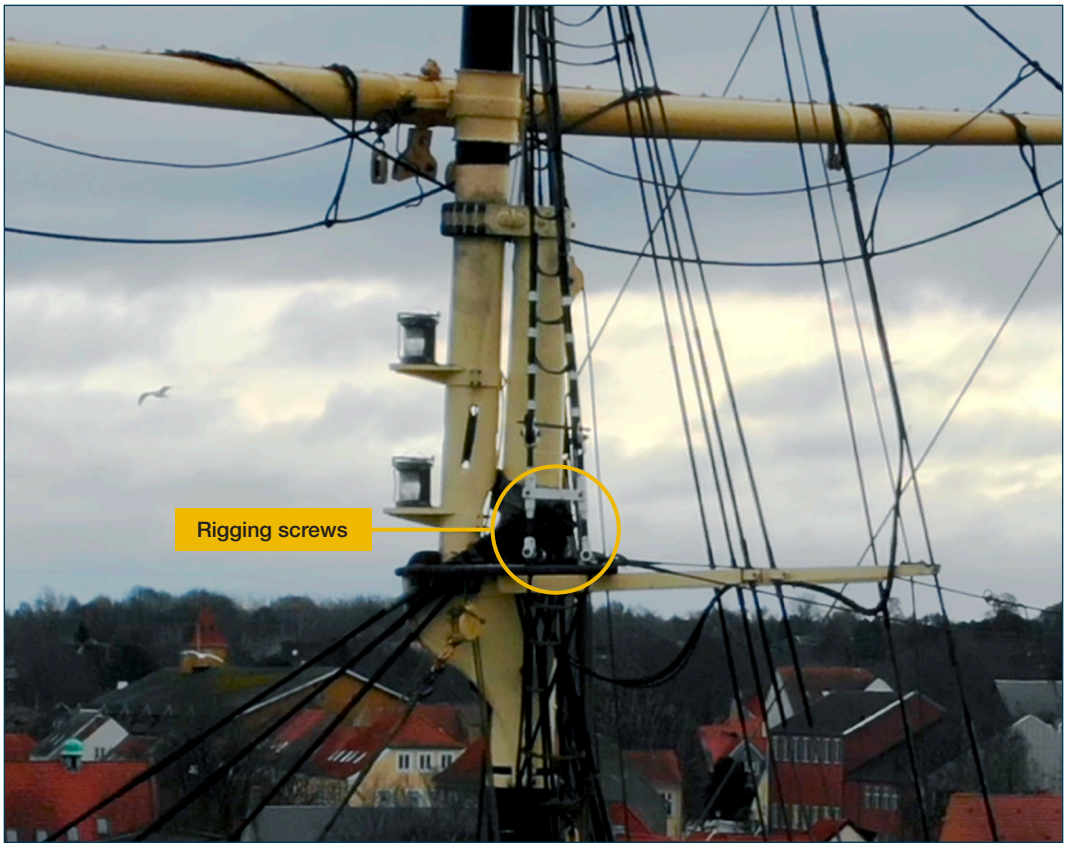

Figure 6: Rigging screw at the topgallant shroud.
Source: DMAIB

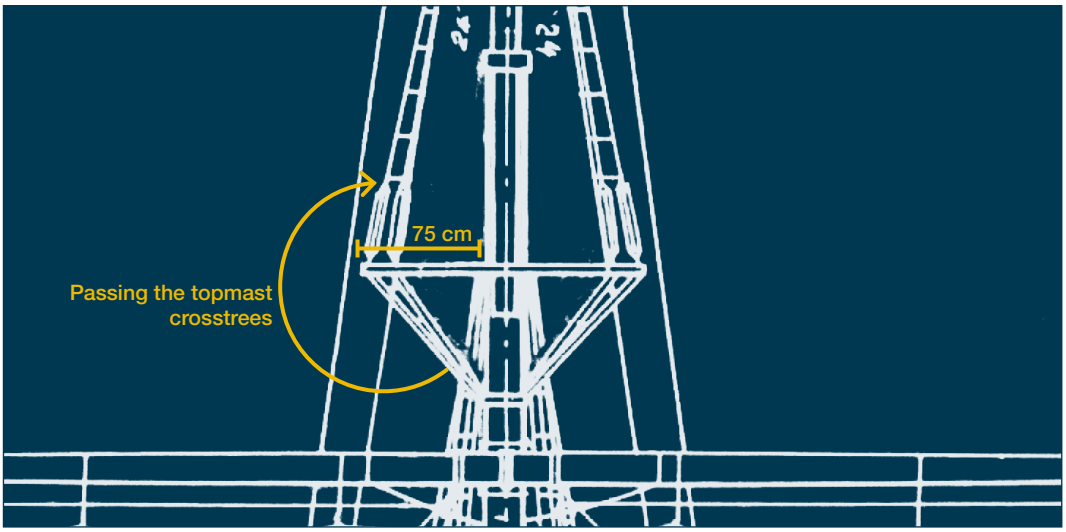

Figure 7: Topmast crosstrees on the fore-topgallant mast
Source: Nakskov Shipyard/DANMARK, modified by DMAIB

Figure 8: Topmast crosstrees on the fore-topgallant mast seen from the pin rack
Source: DMAIB

Weather conditions

The chief mate, who was the supervisor on the day of the accident, had emphasised that the wind conditions had to be favourable for the crane to enable the yards to be kept stable while being removed. Weather observation data from the Danish Meteorological Institute showed that in Assens on 16 February 2022 at 11:00 the wind was 6-11 m/s from a southerly direction, precipitation and the temperature was about 5 °C. These observations were consistent with the conditions described by the crew after the accident. After the accident, the crew informed DMAIB that working in the rigging felt cold, but not in a way that made the work more difficult than usual, given the time of year. Moreover, there was no discernible wind affecting the work with the yards.

Equipment and clothing

DMAIB collected and documented the quartermaster's clothing and work equipment. He was wearing typical workwear, i.e. safety shoes with heels which bore the marks of ordinary wear but still retained adequate tread, work pants, woollen underwear and a rain jacket. The quartermaster also wore a safety helmet, which the crew only usually wore when lifting heavy loads at height, and a 2-point fall arrest harness. A safety line was attached to the back of the harness, which had a carabinier hook at each end, and a rope that was used to attach various tools to prevent them from falling. He did not use the safety line during the climb. The quartermaster also carried a pair of gloves to put on if needed, a rigging bag on his back containing a VHF radio, and lifting stops attached to the fall arrest harness.

Health

The quartermaster had a valid health certificate for seafarers and fishermen without remarks. During interviews with the other crew members, no indication was given that he had health problems that could dispute his stay in the rigging, and the autopsy showed no signs of illness. He had been working in the rigging all morning and generally exhibited sufficient physical and mental ability to go aloft.

Safety management system

Background

In 2012, all maritime education programmes were transferred from the Danish Maritime Authority to the then Danish Agency for Higher Education and Educational Support, which obtained ownership of the training vessel DANMARK from the Danish Maritime Authority. Until 2003, the Danish Maritime Authority had been responsible for the operation of the training vessel and had developed a safety management system based on the ISM Code[1], which is an international standard for the safe management and operation of ships.

MARTEC took over the operational responsibility for the training vessel from the Danish Maritime Authority in 2003. Upon transfer of operational responsibility, the safety management system was adapted to the new management organisation and was continuously adapted and updated in subsequent years. In 2010, the working language on board DANMARK was changed from Danish to English, and the safety management system was translated into English. At the time of the accident, the safety management system contained 12 chapters dealing with various aspects of the ship's operation and the relationship between the ship and MARTEC. DMAIB reviewed the safety management system's instructions, procedures and checklists in order to identify the management company's safety strategy regarding work aloft in the rigging.

Work and stay in the rigging

Chapter 7 of the Safety Management System (Planning of operations), appendix 5, contained an instruction entitled "Instruction for Work and Stay in the Rigging", aimed at the ship's crew and students. Its overall purpose was *"... to ensure the prevention of accidents or personal injuries which could be caused by persons, tools or other equipment falling from the rigging"*.

The instruction described the requirements for crew and students climbing the rigging. These covered: physical ability, equipment, attire, behaviour, how tools and other objects should be secured, rescue of persons, and responsibility for the work undertaken. In addition, the instruction included an assessment of the risks of working in the rigging. The content of the instruction implicitly highlighted two hazardous conditions: Persons falling from the rigging and objects that could fall from the rigging and strike a person. The precautions to be taken to prevent persons from falling from the rigging were mentioned in the sections "Entering the rigging requires" and "Behavior in the rigging".

1 International Safety Management (ISM) Code

QUOTE

”Entering the rigging requires

- *Instruction in accordance with this procedure.*
- *An evaluation of the needed physical strength. As a minimum, every person entering the rigging should be able to pull themselves up twice by the arms. The Chief Officer must evaluate each person, taking into account his or her height, weight and strength, in order to determine whether or not the specific person can enter the rigging.*
- *Permission to enter the rigging must be granted from the OOW, who must also be duly notified when everyone has returned to the deck (an order from either quartermaster on watch or OOW to enter always implies permission).*
- *Proper attire: Shoes or boots, working rig/oilskin, safety harness. (No gloves or mittens can be worn in the rigging unless approved by the Chief Officer.)*
- *Assurance that the necessary braces, downhauls and lifts are all tight and belayed. It is the responsibility of the OOW granting permission that this has been checked.”*

The first part described the precautions to be taken before entering the rig:

QUOTE

”Behavior in the Rigging

- *As silent as possible, and always careful behavior.*
- *When a person in the rigging comes to a stopping point where the time to secure and release the safety hook is shorter than the time standing still, the safety harness must be hooked onto the standing rigging to ensure that a free fall of 0.5 meters is possible. (On the yards, this is possible by leading the harness around the back wire and back into the harness.)*
- *“On deck” is the term used to obtain contact and help from below. This call is to be answered by anyone on deck hearing the call, repeating “On deck”.*
- *If anyone in the rigging feels uncomfortable or ill, the safety harness must be hooked in, and they must call for help.*
- *When in the shrouds, feet should be placed in separate ratlines. Ratlines are never to be used for holding onto or hooking the safety harness onto.“*

The second part of the instruction described the requirements for behaviour in the rigging: The instructions for work and stay in the rigging were thus intended to ensure that persons were physically prepared, had the right equipment and behaviour, and had made sure that the rigging was ready to climb. The instruction ended with the following risk assessment:

QUOTE

"Risk: Moderate Risk (Consequence: extremely harmful & Likelihood: highly unlikely) Recommended controls: continuous focus."

The risk assessment considered a probability of falling down and a recognition that the consequence would be very serious. It concluded that the overall risk would be moderate (low probability x high consequence = moderate risk). The way to manage this risk was for persons in the rigging to keep continuous focus when staying and working in the rigging: "Recommended controls: continuous focus".

In addition to the instructions for work and stay in the rigging, MARTEC had organised a detailed training course for the DANMARK's students, which was described in the safety management system. The training course syllabus included how to communicate and climb the rigging in a safe manner. After completing the training course, students were ready to climb in the rigging on their own. These instructions constituted the safety standard that the management company had set for work and stay in the rigging.

Interviews with the crew showed that the crew knew about the instructions that were relevant for staying and working in the rigging, as well as how the training course for the students was organised. They could not explain the content of the instructions in detail, but had an understanding of their content and use. The content of the instructions was considered as core to their professionalism, and as a result they had no need to consult the instructions when working in the rigging. However, it was common for the instructions for training the students to be printed out and brought on deck during lessons. In this way, the crew ensured that the training was covered the syllabus.

Climbing practices

DMAIB conducted interviews with the management company and the crew in order to clarify the climbing practices used by the crew in the rigging. The ability to climb was ensured by the planned step-by-step training course, which encompassed a total of about 10-15 hours, depending on the individual's technique and mind-set. The crew expressed that especially the fear of heights was one of the main challenges for the students.

The quartermaster had previously been a student aboard DANMARK and had completed the training course. In addition, he had experience climbing the rigging when working on other sailing ships.

The basic technical climbing skills were improved as crew and students gained experience. In addition to mastering a particular climbing technique, it was important to utilise an effective communication with agreed commands, which were described in detail in the safety management system. It was equally significant that any behaviour that interfered with a person's focus when climbing was also not tolerated. For the deck crew, the proper behaviour in the rigging was perceived as a fundamental professional skill.

The climbing technique was based on knowledge and experience of where the feet should be placed and where the hands should grasp to three points of contact (two hands and one foot or two feet and one hand) with the rigging.

In addition, there were requirements for which parts of the rigging to hold or stand on. The general rule was that the feet should be placed in separate ratlines, and the hands should be holding on to an upright steel shroud.

Traversing the top and topmast crosstrees had to be carried out with caution. When ascending, a person had to lean backwards to negotiate the overhangs. In addition, the ratlines under the crosstrees were very narrow and required the feet to be angled a particular way to enable a person to push/lift themselves onto the crosstrees (figures 9 and 10).

Figure 9: Shroud under topmast crosstrees on the fore-topgallant mast.
Source: DMAIB

Figure 10: Feet in ratlines under the topmast crosstrees (in the mainmast).
Source: Kasper Feder, YouTube (dk), 2021

Climbing the shrouds, passing the top and the topmast crosstrees and climbing out onto the yards had to be done using various techniques which required a certain level of knowledge and focus on where to hold onto and stand, and how to transition when moving.

Some activities in the rigging such as climbing out on a yard or traversing the crosstrees, presented more difficulties than others in the event of a person losing their footing or grip. In such situations, there was an increased reliance on physical strength to move on or back.

Using gloves while climbing the rigging was usually discouraged because the sensitivity of the hands, which was essential to ensuring a good grip on the rigging, was reduced. In addition, appropriate footwear i.e., work shoes with heels to prevent slippage in the ratlines, was essential to ensure a good foothold.

As described in the instruction for work and stay in the rigging, a fall arrester was only to be used when a person stood still in the rigging for longer than it would take to fasten the safety line. That is, a fall arrester was used in stationary work where three points of contact could not be maintained, or if a person felt unable to maintain three points of contact through exceptional reasons such as exhaustion. In practice, this meant that a fall arrester was not used when persons in the rigging were in motion, with the exception of work on the yards, where there was always a requirement to be secured with a fall arrester.

There was widespread scepticism among the crew and in the management company towards using any kind of fall arrester equipment during climbing. The crew and management company personnel perceived that the use of the equipment would introduce problems that introduced new hazards when climbing the rigging, for example when using the safety hooks during climbing. In addition, the use of a fall arrester could create a sense of safety that could reduce the individual's focus on their own climbing technique. The danger of falling down motivated crew and students to stay focused on the correct climbing practice.

According to the management company, the ship had had various professionals visit to provide guidance on fall protection solutions, but they had not found a workable solution that the management company and crew found safe and practical. It was generally considered safe to climb the rigging without a fall arrester, because there had been no fall accidents that had resulted in serious injury to crew or students in the last 20 years. During which there had been thousands of work activities undertaken aloft.

Legislation and regulatory oversight

Applicaple rules

DMAIB reviewed legislation[2] and industry guidelines[3] related to work at height on merchant ships in order to identify the requirements for various types of safety measures associated with working at height. The starting point in both the legislation and the guidelines was that there should be protection against falls, if there was a risk of a drop with a free fall of two metres or more. When working on ladders, fall protection had to be established, if the ladder was more than 5 metres high and had an angle of more than 70 degrees relative to the horizontal plane. As far as possible, the risk of a drop should be reduced by the structural design of the workplace, e.g. handrails, back braces or similar measures with the same level of safety. Where this was not possible, anchorage points for fall arrest equipment were to be installed.

Onboard DANMARK, the shrouds leading from the top to the topmast crosstrees were greater than 70 degrees relative to the deck, and no structural arrangement of the shrouds reduced the risk of a drop. It was common in the sailing ship industry in Denmark not to use structural devices for fall protection. Therefore, in order to comply with the applicable legislation and guidelines, alternative safety measures were required to be introduced to reduce the risk of a drop. The crew of DANMARK were under the impression that the necessary measures had been taken in accordance with the Danish Maritime Authority's rules for work at height.

The Danish Maritime Authority's supervision before the accident

DMAIB reviewed the DMA's annual audit reports of MARTEC with regards to the safety management system for the period 2018-2022. The 2018 audit report stated that working conditions at height, including when climbing the rigging, were discussed. It also mentioned that new safety measures should not introduce hazards greater than the hazard they were intended to reduce. The use of fall protection devices while working in the rigging and the additional hazards this brought were discussed. In conclusion, the audit report noted that MARTEC and the ship would explore possible solutions to improve safety. The annual audit reports from the period 2019-2022, work and climbing in the rigging were not mentioned.

2
- Order no. 1246 of 11 December 2009 on Notice A from the Danish Maritime Authority, technical regulation on occupational health in ships, as amended.
- Order no. 9070 of 20 December 2005 on Notice A from the Danish Maritime Authority, occupational health in ships, chapter A VII, personal protective equipment, 1 January 2006.
- Order no. 846 of 25 June 2018 on safety work on board merchant ships (occupational health on board ships).
- Notice A from the Danish Maritime Authority, occupational health in ships, chapter VI, technical aids, 5 July 2004.
- Order no. 1512 of 8 August 2016 on Notice B from the Danish Maritime Authority, the construction and equipment, etc. of ships, as amended, chapter II-4, regulation 7.

3 SEA HEALTH & WELFARE. Fall protection (2020).

The Danish Maritime Authority informed DMAIB that since MARTEC became the operator of the training vessel, there had been occasional discussions regarding the use of fall arresters in connection with climbing DANMARK's rigging. The deviation from the general rules on the use of fall protection equipment has been accounted for with the consideration of not adding more hazards when climbing the rigging. In addition, the ship had demonstrated for over 20 years that the climbing practice had been safe, because it could be statistically shown that there had been no fall accidents that led to serious injury or death. The risk associated with climbing the rigging without fall protection was deemed to be acceptable and the ship was not required to introduce further fall protection measures.

On the day of the accident, the Danish Maritime Authority carried out an inspection visit and prepared an inspection report. The report stated: "Procedures must be implemented to ensure against falls from heights. Work in the rigging must not resume until new procedures are implemented." These requirements had to be met before departure.

The Danish Working Environment Authority's inspection after the accident

The Danish Working Environment Authority also carried out an inspection visit to the ship on the day of the accident, because the maintenance work could be characterised as being maintenance and repair work under shipyard or shipyard-like conditions. During the inspection, the Danish Working Environment Authority issued an immediate injunction to the management company, which required effective measures to be taken to prevent the risk of a fall when working in the rigging. The inspection report stated that the work at the time of the accident was not planned or organised or carried out in a way that was fully justified in terms of safety, particularly as no effective measures had been put in place to prevent a fall. Emphasis was placed on the following:

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- *"The deceased climbed the rigging at a height of up to 20 metres above deck.*
- *The deceased was wearing an H-harness with two carabiner hooks, but did not attach the carabiners to suitable attachment points in the rigging during movement in the rigging. Thus, he was not secured against a fall until he reached the final place of work at height.*
- *The deceased fell from an estimated height of 20 metres when he had to pass the topmast crosstrees.*
- *The deceased presumably lost his grip on the shroud when he had to climb the topmast crosstrees by swinging one of his legs up onto the topmast crosstrees.*
- *The work was carried out at a height of more than 5 metres.*
- *For the reasons mentioned above, it is the Danish Working Environment Authority's assessment that the work was not carried out in a safe manner. It was also stated that the work was planned in such a way that the employees were not protected against falls when moving about in the rigging, as the fall protection was to be attached only after reaching the place of work at height. It is thus the assessment of the Danish Working Environment Authority that the work was also not planned and organised so that it could be carried out in a safe manner."*

Analysis

The accident

The quartermaster's fall from the rigging occurred during normal, periodic maintenance work, during which the work progressed according to plan, and the quartermaster performed tasks with which he was familiar. To him, the climb up the fore-topgallant mast was routine.

There were no witnesses who could provide accurate knowledge of what happened when he lost his grip and fell. The rigging showed no signs of damage or defects, and there was nothing to suggest that he experienced any problems during his ascent. DMAIB consequently focused the investigation on other matters that had an impact on the quartermaster's climbing in the rigging.

The quartermaster was seemingly in good health and there was nothing that indicated he might have lost his grip on the rigging due to discomfort or a loss of consciousness due to a medical event. Furthermore, there was no indication that he did not have the physical and mental ability to work at height in the rigging. The other crew members did not find that the weather conditions were unusual or hampered the work, considering that the work was carried out while the ship was alongside in February. However, it cannot be ruled out that working in the cold may have had an impact on the quartermaster's ability to hold on to the rigging without gloves on. The clothes that the quartermaster was wearing were normal for the work he performed. There was no indication that any item caused him any problems in relation to his freedom of movement, or any item was a snagging hazard. In addition, no injuries were found on his shoes that could affect his footing in the ratlines. And there was no indication either that his rigging bag or straps were caught in the rigging.

Since the above conditions could not explain why the quartermaster lost his grip, the fall of the quartermaster most likely had to be due to conditions related to the way the climb was carried out. The investigation showed that the usual three-point safety stance when climbing the rigging did not provide the quartermaster the same safety at all positions in the rigging. Climbing in the shroud up to the top and topmast crosstrees was characterised by the fact that he was to some extent supported by the shroud, because it was at an angle from the railing towards the ship's deck. But immediately under the top and the topmast crosstrees, the shroud slanted in the opposite direction, which would have required the quartermaster to support his own weight. In these locations, his climbing technique and physical ability became crucial, because he was unable stop and rest at these points. The quartermaster fell while in the topmast futtockshroud, where the ratlines narrowed markedly and a specific positioning of the feet was required when passing the topmast crosstrees. If problems arose at this point, it was necessary to change the foot position, which may have compromised the quartermaster's three-point safety stance and challenged his physical endurance. However, the investigation has not been able to unequivocally identify the exact problems the quartermaster experienced when passing the topmast crosstrees, that caused him to lose his footing and grip on the shroud.

The use of the safety line when passing the top and topmast crosstrees would have required the quartermaster to handle and secure the line in a situation where his climbing technique was already challenged and where the safety line would limit his freedom of movement. The use of the safety line at these points in the rigging was not considered possible by the deck crew and was not part of the acquired climbing practice.

Safety barriers to falls from the rigging

Based on DMAIB's interviews with the crew and the management company as well as a review of the management company's safety management system, DMAIB deduced the involved persons' views on the factors that contributed to making climbing in the rigging a safe task to undertake.

The crew's perception of what constituted safety when staying and working in the rigging was largely consistent with the content of the company's safety management system. However, there was a greater level of detail in the way the crew dealt with safety when climbing the rigging. This was due to the fact that on a daily basis they dealt with specific issues that were not assumed to be included in a formalised safety management system. On a daily basis, the crew had to deal with changing circumstances that necessitated adjustments. This variability was on a scale that could hardly be described in a formalised safety management system. This could, for example, be the influence of weather conditions on the wearing of gloves during climbing, and how feet and hands should be placed when passing the top and topmast crosstrees etc.

DMAIB found that the management company and crew's safety strategy for climbing the rigging was based on four types of safety barriers:

1. Climbing technique
It was crucial that individuals possessed the proper climbing technique in the various positions in the rigging. This technique was not only learned by training as a student, but was also a skill that was gained as crew and students expanded their experience working in the rigging. This was especially important when climbing at the most difficult places, such as at the top, the topmast crosstrees or out on the yards. The climbing technique consisted of various rules, which were based on maintaining a constant three-points of contact.

2. Physical ability
In order for the climbing technique to be safe, it was essential that persons who climbed in the rigging had sufficient strength in their arms to lift their own body weight. The requirements of their physical ability were ensured by the fact that everyone had to be able to perform two pullups before they were allowed to climb in the rigging. Persons were not allowed to climb the rigging, if they suffered fatigue, exhaustion or otherwise experienced physical challenges that could cause problems while climbing the rigging. The crew consequently placed great emphasis on both crew and students speaking out, if they were not comfortable with the climbing situation.

3. Use of equipment
The climber's equipment consisted of the correct attire, a rigging bag for carrying tools, and a fall arrest harness. There was a particular focus on using the right footwear with heels, which ensured a foothold in the ratlines. Gloves were generally discouraged during climbing, because they could hinder an effective climbing technique by causing the climber to lose sense of the effectiveness of their grip.

It was a requirement that everyone had to wear a fall arrest harness with a safety line. If health problems arose or physical exhaustion occurred in the rigging, the climber was to attach himself to the rigging with the safety line. In addition, the fall arrester was to be used when working on the yards, where it could not be expected that a constant three-point safety stance could be maintained when working with the sails.

The basic rule was that it was to be used, if a position taken up in the rigging with no movement lasted longer than it would take to secure the safety line. In practice, this meant that a fall arrester was not to be used when climbing the rigging. An important reasoning for not using fall protection was based on the hazard conditions that the use of a fall arrester could introduce. In particular, the work on fastening carabiners could distract the climber from the correct climbing technique. In addition, the use of the fall arrester could produce a negligent behaviour in the rigging, because the danger of falling down was not consciously present in their minds.

4. Behaviour in the rig
It was a requirement that all was quiet in the rigging so everyone could hear the messages given to and from the deck. The crew did not tolerate behaviour in the rigging that could be characterised as play or experimentation with alternative climbing techniques. The purpose of the correct behaviour was to keep mental focus on the climbing task.

The various crew members and the management company had a uniform perception that these barriers were effective in providing safety when climbing the rigging. A view that was supported by the fact that there had not been a very serious fall accident on the ship for more than 20 years. On this basis, the management company and the ship had drawn up the following risk assessment:

“Risk: Moderate Risk (Consequence: extremely harmful & Likelihood: highly unlikely) Recommended controls: continuous focus.” (SMS, chapter 7, appendix 5)

The risk assessment in the safety system in a brief form described the way the management company and crew thought about risk and safety. The probability of falling from the rig was judged to be ‘highly unlikely’, because it could be statistically justified by the absence of accidents. The consequence of falling from the rigging was ‘extremely harmful’, because climbing the rigging took place up to about 30 metres up, from where a fall could result in death. The residual risk following the introduction of the barriers was thus assessed to be ‘moderate’. This residual risk was to be addressed by keeping ‘continuous focus’. It was unknown what risk was left after this measure.

Limitations of safety barriers and risk assessment

DMAIB found that the barriers used had some limitations, which resulted in a problematic way of making the risk assessment.

The limitations of the safety barriers

The barriers were primarily related to hazard conditions that were linked to the individual's conscious behaviour when climbing, e.g. use the equipment provided, climb using the approved technique, stay within the limits of personal physical ability, and stay focussed.

This perception of safety was based on the fact that the individual was not only responsible for his or her own safety in normal work situations, but also in situations where an unexpected situation suddenly arose over which the individual had no control. The safety barriers did not address the possibility of unexpected events where the climber did not have full body control, had spontaneous health problems or lost concentration due to external factors, which are basic conditions in most work situations. Consequently, the barriers were based on a zero-error thinking, and thus there was no mechanism to safeguard a climber who, for one reason or another, reached his own limitations. For example, if a climber suddenly found himself in a critical situation where there was no time to react and/or the requirement to be able to perform two pullups was not sufficient to be able to save himself from a dangerous situation.

Limitations of the risk assessment

When assessing the likelihood of falling from the rigging, the risk assessment took into account the frequency of fall accidents, rather than the potential for hazards to arise that could lead to a fall. It was considered highly unlikely that the barriers put in place would fail in such a way that a person would fall when climbing, because it had not happened in the past 20 years. In other words, the frequency of fall accidents served as a legitimisation of the effectiveness of existing barriers.

From time to time, various types of problems in the rigging were identified, such as when students focused on things other than climbing, or when difficulties arose in finding a foothold in the narrow ratlines under the top or the topmast crosstrees, which showed that the danger could vary when climbing in different places in the rigging. These problems were not seen as weaknesses in the effectiveness of the barriers, but rather reinforced the need to remind crew and students to stay focused on the barriers already established. For this reason, the parties involved could accept that the risk of climbing the rigging was 'moderate' with a consequence which was 'highly damaging'.

That there was widespread scepticism in the management company and among the crew regarding measures that could reduce the consequence was shown by the attitude of those involved to various types of fall protection. The concern regarding the use of fall protection was that the probability of falling would increase, which was considered more critical than the benefit of the reduced consequence. In addition, the very serious consequence of a fall from the rigging was considered to be beneficial for the effectiveness of the barriers, because persons who climbed the rigging would be more motivated to adhere to the correct climbing practices.

Measures to reduce the risk of climbing the rigging were that persons must, when in the rigging, continuously stay focused ("continuous focus"). However, since the probability was already assessed to be very unlikely, this measure would not reduce the risk further, but simply maintain the existing (un)likelihood of the climber falling down. On the other hand, a measure to reduce the impact of the consequence could reduce the risk. That is, a measure that reduced the severity of the injuries to persons resulting from a fall from the rigging, e.g. various kinds of barriers that could prevent, stop or soften the fall. The risk assessment indicated a bias towards probability in preference to consequence. This was based on a general acceptance that the risk when climbing the rigging was only moderate. As a result, the potentially severe consequences were not given sufficient weighting.

Conclusion

Accident causation

On 16 February 2022, a quartermaster on the training vessel DANMARK died after falling about 25 metres from the topmast crosstrees on the fore-topgallant mast. The accident happened while the ship was undergoing regular maintenance work before an upcoming shipyard stay.

DMAIB's investigation aimed to identify the circumstances of the quartermaster's fall from the rigging and to determine what barriers were put in place by the crew to avoid falls. It was not possible to establish the exact circumstances which caused the quartermaster to lose his grip on the shroud and fall from the rigging. Nothing unusual was found that caused him to fall, such as the condition of the rigging or weather conditions, Therefore, it is likely that something occurred during the climb which interfered with his usual climbing technique that caused the quartermaster to suddenly and unexpectedly loose his grip and footing.

The barriers put in place by the crew and the management company were based on the fact that persons in the rigging had to possess a climbing technique, have the physical ability, have the appropriate equipment and have continuous focus while the climb was carried out. These barriers placed the onus on individuals for their own personal safety. None of the barriers addressed those instances in which an unexpected dangerous situation suddenly arose. If, when climbing the rigging, a person for one reason or another suddenly lost his grip and footing, there was no means of recovering the situation. That is, nothing was provided to supplement a climber's responsibility for their own safety in order to prevent serious injury or death.

From the viewpoint of the management company and the crew, the use of a fall arrester when climbing was not only considered problematic because its use could detract from the expected climbing practices, but also because it could engender a sense of security that could impact on a climber's focus. The fear of the very serious consequence was thus considered essential to the effectiveness of the existing barriers.

DMAIB found that the Danish Maritime Authority, the management company and the crew had a general acceptance of a moderate risk when climbing the rigging because the safety barriers had demonstrated a statistical effectiveness. That is, there had not been a fall accident with very serious consequences for more than 20 years, which justified that the barriers that had been put in place made it highly unlikely that anyone fell from the rigging while climbing. This way of thinking about safety presupposes that no new situations could arise in which a person climbing the rigging could find himself in a unique situation. Such as a situation where the person suddenly lost his footing.

When the quartermaster unexpectedly lost his grip on the rigging at the topmast crosstrees, he fell with no possibility of the fall being softened or stopped, because there was no barrier to save him. When the quartermaster fell from the rigging, he was exposed to the serious consequence accepted in climbing the rigging. A consequence that included extremely serious repercussions, which in his case resulted in fatal injuries.

Safety learning

Avoiding accidents only by governing the crew's behaviour through work descriptions and instructions relies on the notion that it is possible for the individual to achieve full control over his own work situation.

However, it is a basic condition that full control is in fact not achievable. As long as the possibility of loss of control is not recognised and dealt with, the crew will be unprotected from the dangers that may arise. It is especially problematic in situations where a slight deviation can lead to fatal consequences.

On DANMARK, the focus was primarily on behaviourally regulated safety initiatives in connection with climbing the rigging, because the need to maintain a traditional ship design – and thus traditional working methods – made it difficult to change the ship's construction or opt for equipment solutions which required extensive training.

Preventive measures

Actions by MARTEC

Following the conclusion of the investigation, DMAIB has received the following information regarding actions from MARTEC:

"A working group consisting of crew from the training vessel DANMARK, MARTEC's instructors in rescue from aloft, masters and chief mate from GEORG STAGE, as well as external persons from suppliers of equipment for climbing and fall protection, has come up with a solution that minimises the consequence of falling from the rigging.

The horizontal movement in the rigging on the yards had an existing safety measure; this safety measure is described in the ship's procedure (Chapter 7 – Appendix 5 Instruction for Work and Stay in the Rigging).

The new solution ensures against falls in connection with vertical movement up/down from the deck, horizontal movement on the platforms and horizontal movement between the shroud and the lower and fore-top yards. The solution takes into account the particular need of a sailing ship to achieve necessary mobility when staying in the rigging. Ropes approved for fall protection are set up and fixed anchor points are used. Crew and students must connect to the ropes with a "rope lock"), the rope lock is connected via top ropes to an approved H-harness.

The new solution for protection against falls from a height is a supplement to the current practice for crew and students' work in the rigging. Training for work in the rigging and current requirements for physical fitness will continue to apply. The procedure (Instruction for Work and Stay in the Rigging) constitutes an integral part of the "know your ship" programme for students and crew members who are going aloft.

The new solution and associated procedures have been demonstrated and approved at a meeting with the Danish Working Environment Authority and the Danish Maritime Authority on 29 April 2022. However, the solution should not be considered a permanent unchangeable solution. It will evolve in line with the experience gained on board, through the exchange of experience and through cooperation with other sailing ships in the industry, so the safety of movement in the rigging is continuously optimised.

With the new solution, redundancy is ensured to the personal responsibility for safety."

MARTEC

Appendix

SHIP'S DATA

Name:	DANMARK
Ship type:	Training vessel, sail
Nationality:	Denmark
Port of registry:	Copenhagen
Call sign:	OXDK
IMO number:	5086279
DOC company	MARTEC
IMO company no.:	5355028
Year built:	1933
Shipyard/shipyard number:	Nakskov Shipyard A/S/DEN007019
Classification Society:	Det Norske Veritas (DNV)
Length overall:	64,98 m
Brea overall:	10,00 m
Maximum draught:	6,00 m
Gross tonnage:	737
Propulsion power:	357 kW
Hull material:	Steel
Hull type:	Single hull

SEJLADSDATA

Port of departure:	Frederikshavn, Denmark
Port of arrival:	Assens, Denmark
Voyage type:	National, coastal
Information about the cargo:	None
Manning:	9
Number of passengers:	0

WEATHER

Wind – direction and speed:	10 m/s fra sydlig retning
Current:	Unknown
Wave height:	0,2 m
Visibility:	Good
Weather conditions:	Cloudy/precipitation
Light/dark:	Daylight

INFORMATION ABOUT THE ACCIDENT

Type of marine casualty:	Occupational accident
IMO Classification:	Very serious
Date and time:	February 16, 2022, 11:46 A.M.
Place of the accident:	Assens Havn
Ship operation and travel section:	Alongside, in port
Human factors:	Yes
Consequences:	One crew member perished.

ASSISTANCE FROM AUTHORITIES ON LAND AND EMERGENCY SERVICES

Parties involved:	Funen Police, ambulance and medical car
Response:	Approx. 10 minutes.

RELEVANT CREW MEMBERS

Deceased quartermaster:	23 years old. Had been a student on DANMARK in 2019 and worked on various sailing ships since. Signed on DANMARK in 2022.