DMAIB
DANISH MARITIME ACCIDENT
INVESTIGATION BOARD

STONE I

Marine accident report on loss of control

4 JANUARY 2020

Content

Board statement

On 4 January 2020, the Marshall Island registered chemical/oil products tanker STONE I was loading vacuum gas oil at Ensted Oil Terminal, Denmark, when the ship started to drift uncontrollably from the jetty during a sudden increase in wind speed. The ship's crew and the terminal operators immediately initiated an emergency stop procedure for the loading operation, but were not able to stop the ship breaking away from the berth in time. As the ship drifted from the jetty, the loading arms on the terminal was torn from the ship's manifold, resulting in a gas oil spill. No persons were injured during the accident.

DMAIB launched an investigation of the accident due to the severity of the oil spillage and the damage to the jetty. The investigation aimed at clarifying what caused the ship to break away during the loading operation. The investigation comprised examination of STONE I's mooring winches, the weather conditions at the time of the accident, the mooring layout on STONE I, and the layout of the jetty at Ensted Oil Terminal.

In the report it is established that the mooring layout on STONE I and the layout of the terminal berth was not compatible, resulting in a mooring configuration, which reduced the ship's actual mooring restrain capacity. STONE I's moorings were thus not able to withstand the suddenly deteriorating weather conditions, resulting in a momentary loss of control of the ship.

Narrative

Reconstruction of the events

The description of the course of events covers a period from STONE I approached Ensted Oil Terminal at 2300 on 3 January 2020 to the loss of control situation was under control at approx. 1000 on 4 January 2020.

The reconstruction of the course of events was based on VDR recordings, CCTV, log book, bell book and photos. Events are presented in the chronology in which they were acknowledged by the involved persons. The course of events are described from the perspective of the involved persons to give insight to how the events were perceived before the accident was evident.

Background

STONE I (figure 1) was a Marshall Island registered chemical/oil products tanker primarily trading between ports in Northern Europe. On 2 January 2020, the ship departed Hamburg in ballast condition and was bound for Ensted Oil Terminal in Aabenraa Fjord, Denmark, where the ship was scheduled to load vacuum gas oil on 4 January 2020. This was first call at Ensted Oil Terminal for the crew on STONE I. In the morning of 3 January 2020, STONE I arrived at the anchorage outside Ensted Oil Terminal waiting for the berth to become available. The master and his officers reviewed the weather forecast and did not expect any adverse weather during the port stay.

Figure 1: STONE I
Source: DMAIB

Course of events

Loss of control

Late in the evening on 3 January, STONE I was notified that the berth at Ensted Oil Terminal was available, and the pilot was ready to bring STONE I alongside. The anchor was weighed at 2300 and approximately half an hour later the harbour pilot embarked, and the ship proceeded to the terminal. During the approach to the jetty, the pilot was presented with the ship´s pilot card containing ship specific information. The master and the pilot used the ship´s pilot card to exchange information, inter alia the ship's draught, the mooring layout of the ship and the ship's handling characteristics. Additionally, the master and the pilot planned the arrival and mooring at the terminal's south jetty. It was agreed that two tugboats would assist during berthing; one tugboat would be made fast aft, and the other would push on the starboard bow. They also agreed on a mooring pattern of 12 lines: two head lines, two stern lines, two forward breast lines, two aft breast lines, two forward spring lines and two aft spring lines. The pilot informed the master that the current alongside inside the fjord was negligible. STONE I then proceeded to Ensted Oil Terminal (figure 2).

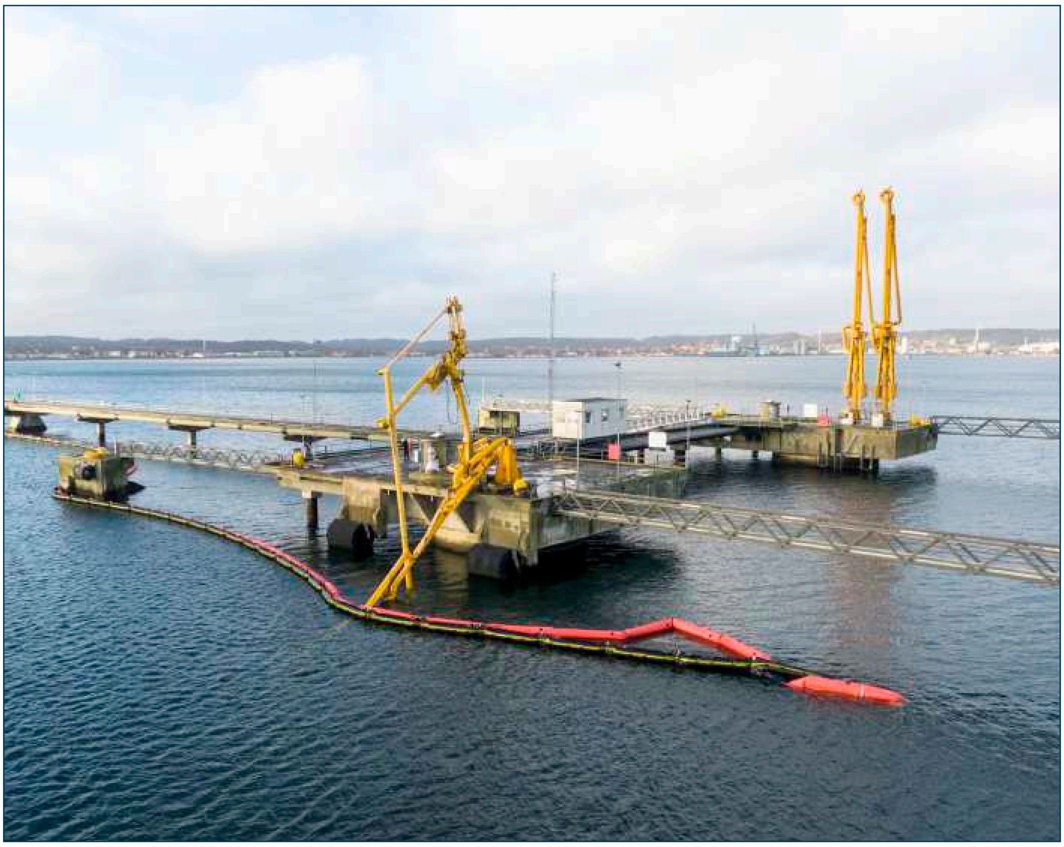


Figure 2: Ensted Oil Terminal after the accident
Source: DMAIB

At 0100 on 4 January, the ship was berthed with port side alongside, and the mooring operation commenced. While handling mooring lines on the aft mooring station, the 3rd officer informed the master on the bridge that the two mooring lines, which were intended to be used as aft breast lines, had to be directed aftwards and fastened to the mooring hooks located aft of the ship. This meant that they would not have a perpendicular orientation to the longitudinal centre line of the ship. The pilot informed the master that the location of mooring hooks and bollards on the terminal did not make it possible to have breast lines as planned. The master discussed the inexpedient direction of the breast lines with the pilot, and the master accepted that it was not possible to use an alternative mooring configuration, and the ship was made fast accordingly.

When the mooring operation was completed at 0115, the terminal loading master and the chief officer completed the terminals ship-shore safety checklist. Meanwhile, the crew on deck prepared the ship for loading which was commenced at 0335.

At 0925 loading was still ongoing, and the chief officer was in the cargo control room monitoring the operation. Through the windows in the cargo control room he observed a sudden and forceful increase of the wind speed, and he felt the wind acting on the ship. The chief officer was concerned, whether the wind exceeded the terminal's wind criteria for the loading operation, and he called the 3rd officer and told him to go to the bridge to read the wind speed on the anemometer. From the bridge the 3rd officer confirmed that the wind speed had exceeded the limit of 20 m/s which was agreed with the terminal to be the maximum limit for stopping the loading operation. The chief officer immediately called the master in his cabin, and asked for permission to initiate an emergency stop of the loading operation, which the master immediately approved. The crew on deck activated the emergency stop device located by the manifold, and the chief officer communicated the emergency stop of the loading operation to the terminal, which was acknowledged.

When the master received the call from the chief officer, he went to the window in his cabin to find out what was happening on deck. Suddenly, he heard a loud noise from the manifold and saw oil gushing from a crack between the loading arms and manifold, and he rushed to the bridge (figure 3, next page). At the bridge, he observed that the ship's stern had drifted 5-10 metres away from the jetty and that the ship was now engulfed in a hailstorm. The master immediately called the engine room and requested to have the engine ready and on bridge control as soon as possible, as the ship was in an emergency situation. The master called all crew on deck to respond to the oil spill. The master was concerned that the ship would drift too close to the shallow water aft of the ship, and therefore ordered the officer and the able seaman (AB) on the forecastle to lower the port anchor to sea level and to be standby for letting it go to stop the ship moving aftwards.

Simultaneously, at 0930, the master received information from the deck crew that one of the aft spring lines had parted. An AB who was standby at the manifold rushed to the forward mooring station together with the 2nd officer. Another AB went to the aft mooring station to assess the situation, but he soon realised that he was not able to safely approach the mooring winches, as the mooring ropes payed out uncontrollably, and the brake bands developed heavy smoke. Both loading arms from the jetty broke off the ship's manifold and vacuum gas oil gushed onto the ship and into the water (figure 3 and 4, next page).

Figure 3: CCTV footage of loading arms breaking off and oil gushing out.
Source: Inter Terminals Denmark EOT Aps

Figure 4: Master's view from bridge at 0930.
Source: Private photo

At 0932, the chief engineer called the master to inform him that the main engine was ready for bridge control. The master wanted to manoeuvre the ship away from the jetty, but the ship was still moored. He called the terminal operators, but he was not able to get in contact with them. Instead he instructed the crew to cut the four head lines. The terminal operators had heard the call from the master, but were too busy with the emergency stop procedure of the loading operation to respond to the call. While the ship was manoeuvred from the jetty, the spring lines became slack, and the terminal operators released them. The four aft mooring ropes ran out, until no more rope was left on the storage drums on the winches. At 0941, the ship was clear of the jetty, and the master informed the authorities that he intended to proceed to the anchorage to assess the situation.

Emergency response

When the terminal operators heard the chief officer ordering an emergency stop to the loading operation, they immediately initiated the emergency procedure for stopping the loading operation. However, the manifold parted from the loading arms before the emergency shutdown was completed. When the terminal operators realised that a serious oil spill was in progress, they called the terminal manager and the local fire brigade.

Shortly after the spill, the authorities deployed the national oil pollution response plan and started containing the oil on the beaches and at sea. It was estimated that 20 m^3 gas oil was spilled on to the ship's deck and 3-5 m^3 into the sea.

Investigation

Scope of the investigation

DMAIB was notified on 4 January 2020 that an oil spill had occurred at Ensted Oil Terminal and that STONE I had broken away from the jetty during loading. Due to the quantity of spilled oil and the damages to the jetty, DMAIB found the accident to be serious and therefore decided to launch an investigation. Two investigators were deployed to Ensted Oil Terminal to gather data from the ship and the terminal.

From the terminal's CCTV recordings of the accident it was apparent that the aft part of STONE I had drifted from the jetty, because the mooring winches gave way when a sudden gust of wind acted on the ship's port side. The aim of the investigation was therefore to establish why the mooring winches gave way and released the ropes on the aft mooring station.

STONE I was still at anchor at a nearby anchorage and engaged in the recovery of the oil spill, when the investigators boarded the ship. During the investigation, it was evident that the aft winches had paid out mooring ropes until empty, a spring line was broken and the rest of mooring ropes on the forecastle had been cut during the emergency. Hence it was not possible to investigate the ship while it was alongside the jetty at the terminal and reconstruct the mooring ropes exact angles to the jetty and determine the ropes' pretension. Due to the hectic circumstances during the emergency, the investigators could not ascertain whether the brakes had been operated during or after the accident. The brakes on winches on the aft deck was found fully or partly released, and offered no cue on how they were applied prior to the accident. Additionally, as the ropes no were longer on the mooring winches on the aft deck, it was not possible to determine how the ropes had been reeled on to the aft winches. Consequently, DMAIB did not have the necessary evidence to reconstruct the exact mooring situation before the accident.

Instead, DMAIB identified the contributing factors that could influence the restrain capacity of the mooring winches. The investigation therefore focused on the winches, the weather conditions and the mooring configuration with the purpose of review the restrain capacity of the mooring winches and the forces acting on the winches at the time of the accident.

Winches

The investigation of the winches comprised their functionality, and how they were operated, to determine if they had malfunctioned or had been erroneously operated.

Winch functionality

STONE I was equipped with eight hydraulically driven mooring winches. The basic layout drawing below (figure 5) below shows the location of the mooring winches. The mooring winches on the aft and on the forward mooring stations were fitted with double split drums divided by a notched flange with a tension section and a rope storage section (figure 6).

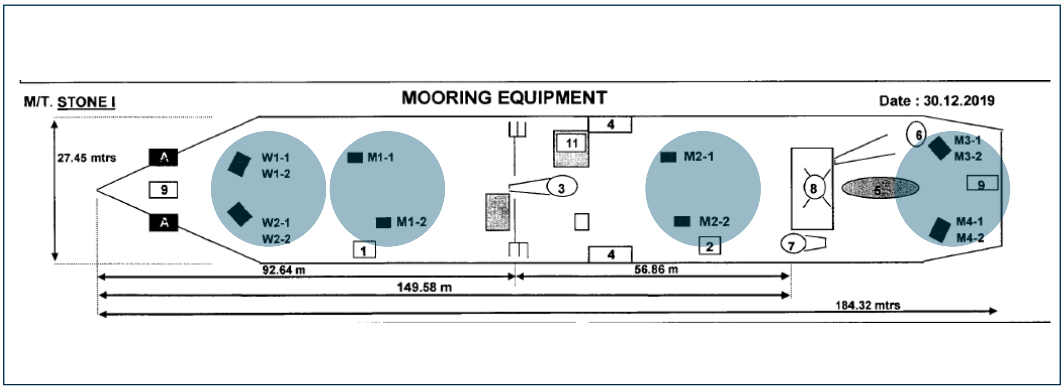


Figure 5: Basic drawing of mooring winch location on STONE I
Source: Zenith Gemi Isletmeciligi AS / DMAIB

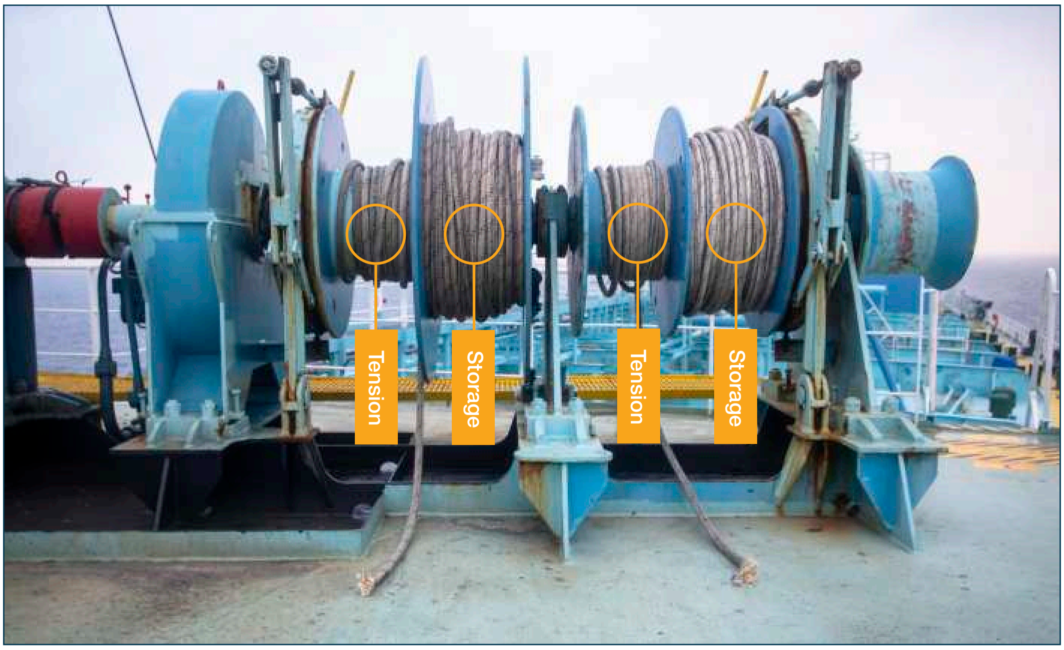


Figure 6: Combined windlass and double split drum mooring winch.
Source: DMAIB

The mooring winches forward of the accommodation and aft of the forecastle intended for spring lines were single split drum mooring winches. On the tension drum, the rope was reeled in one layer. Only the rope reeled on the tension drum was under tension. The winch brakes had a maximum holding capacity of 40.8 tons each, but to allow for a safety margin, the brake holding capacity on the winches was adjusted to 29.4 tons, corresponding to 60 % of the ship's design minimum breaking load.

According to the mooring rope certificates, the mooring ropes installed on the winches were high-modulus polyethylene (HMPE) rope with a diameter of 26 mm connected to an 11 m nylon tail rope with a diameter of 56 mm. The breaking load of the HPME rope was 51 tons and 63 tons for the nylon tail. The breaking load of the rope intentionally exceeded the winches' brake holding capacity, as this ensured the winch brake to pay out instead of the rope breaking, if excessive forces acted on the ship.

The condition of the brake bands was instrumental for the brakes to work as intended. During the investigation, the mooring winches on STONE I were examined by DMAIB. They were not found to be in a state that impaired their functionality. Brake holding capacity tests were performed annually to ensure the correct functioning of the brakes. Prior to the accident a break holding capacity test was conducted in May 2019, which showed that the brakes were found to function as specified. After the accident in January 2020 and in February 2020, while the ship was dry-docked, break holding capacity tests were carried out again. Both tests showed that the brakes were in good working order. As the brakes were found to be in functional order, it can be concluded that the winch brakes did not pay out due to malfunctioning brakes.

Operation of the winch

Each winch was fitted with a manually operated clutch and band brake with manual setting and release. The brake was tightened by turning the hand wheel (figure 7).

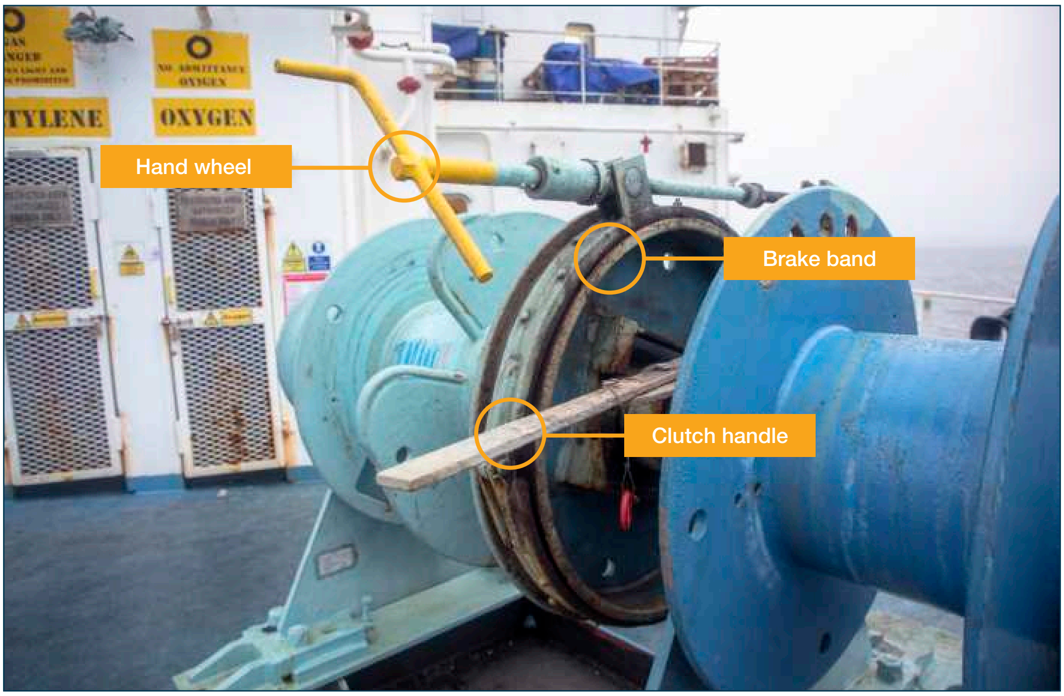


Figure 7: Hand wheel, brand brake and clutch on mooring winch.
Source: DMAIB

The hand wheel was connected to a threaded rod that drew the upper and lower halves of the brake band together (figure 8), which brought the brake band into contact with the brake drum. Brake setting indicator nuts for the spring load were fitted on the rod close to the hand wheel, visually indicating whether the brake had been properly calibrated. Paint markings on the threaded rod indicated how much the brake had been tensioned (figure 9). These visual cues had the purpose of enabling the crew to determine, whether the brakes were properly tensioned. The paint marking on the threated rod indicated two turns on the rod. Hence, the visual indicators made it readily visible for the deck crew to determine if the brakes were sufficiently applied.

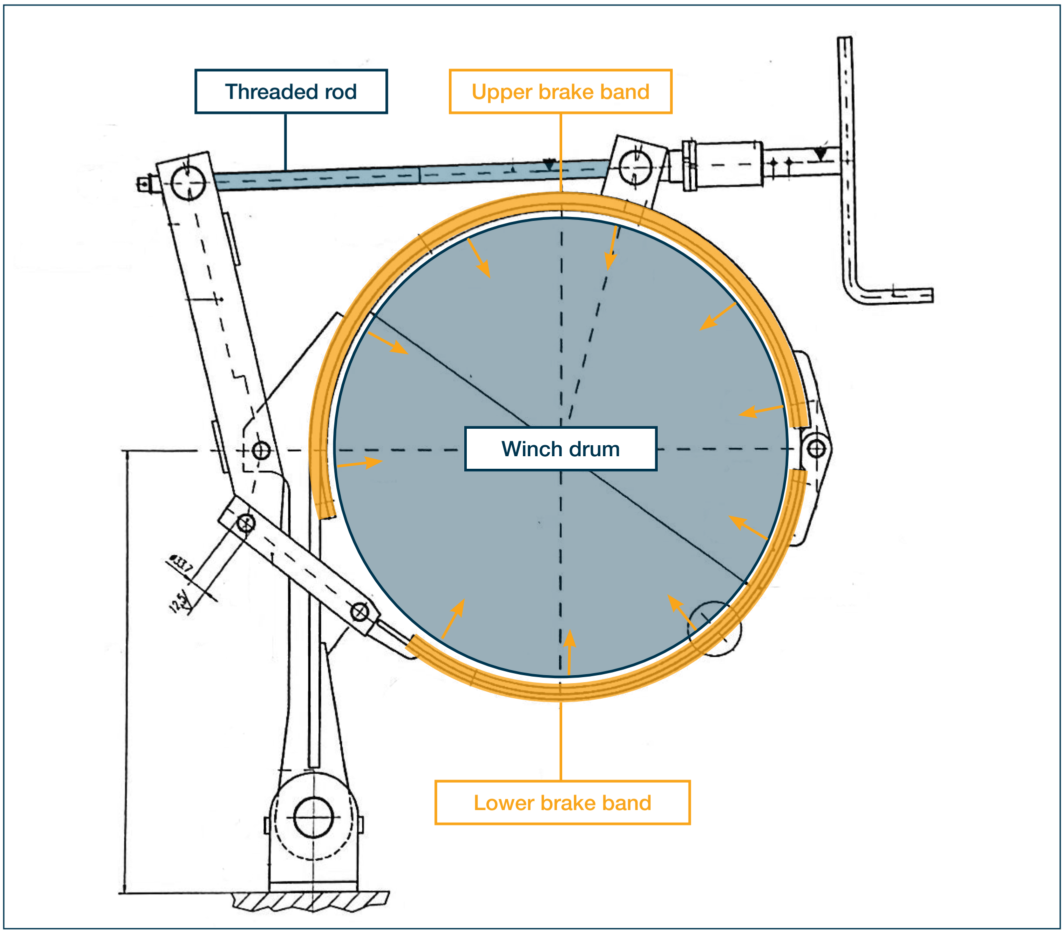


Figure 8: Basic drawing of mooring winch
Source: Zenith Gemi Isletmeciligi AS / DMAIB

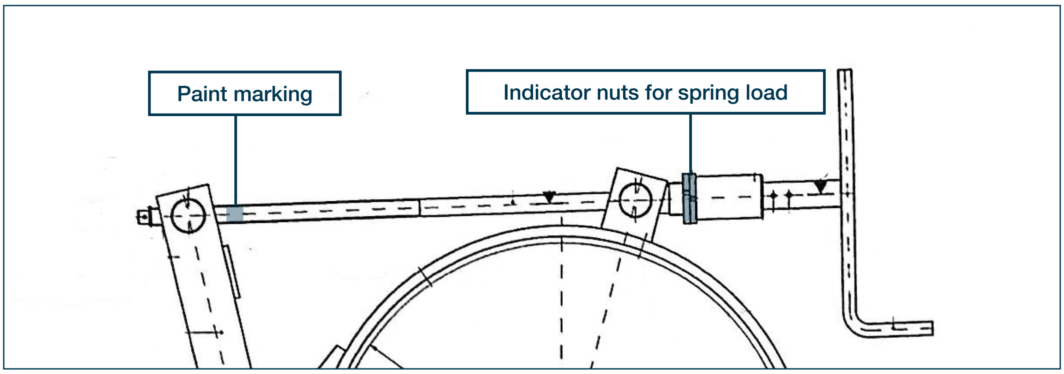


Figure 9: Visual indicators on the winch brake
Source: Zenith Gemi Isletmeciligi AS / DMAIB

During the investigation on board, DMAIB conducted interviews with the deck crew to establish mooring practices, and the crew demonstrated how the winches were operated. The demonstration showed that using the visual indicators was an integral part of the crew's work practices when monitoring the winches during rounds on the deck and when operating the winches during mooring operations.

During the investigation on the ship, it was not certain whether the winches had been adjusted during or after the accident. Therefore, it was not possible to determine on site if the winch brakes had been fully applied before the accident. Statements from witnesses affirmed that the brakes on the aft deck winches made a screeching sound and developed smoke, caused by friction between brake band and brake drum, when the ship drifted away from the jetty. This indicated that the brakes were tightened prior to the drifting of the ship; however, it did not verify whether the brakes had been fully or only partially applied.

The winch brake bands were designed to work in one direction only. Therefore, the rope needed to be reeled correctly on to the winch drum. During the investigation of the winches, DMAIB found that a red arrow on the winch marked in which direction the rope was to be reeled on to the winch drum. However, on the winches on the aft deck, the arrow pointed in the wrong direction, but was painted over. As the ropes on the forecastle winches were reeled up correctly and the crew had covered the arrow on the aft winches with paint, it indicates that the crew was aware of the correct way of reeling the rope on to the winch. Therefore, DMAIB did not find indications that the mooring ropes were reeled on to the winch drum incorrectly.

Findings

- The winches did not malfunction.
- Evidence shows that the brakes on the aft winches were applied before the accident, but not to which extent.
- The presence of visual indicators on the winch brakes provided readily available indication of the correct tensioning of the brake, and the crew was familiar with the use of the indicators.

Wind

Weather forecasts

Prior to arrival at Ensted Oil Terminal, the master and the navigational officers had reviewed the weather forecasts for arrival and the duration of the port stay. Available weather data was obtained from the ship's weather forecast application 'Chart Co-One Ocean' supplied by the company. The application presented the wind speeds as average wind speeds and gusts as maximum wind speeds. The application forecasted average wind speeds of 10 m/s with wind gusts of up to 13.5 m/s.

These weather conditions were not out of the ordinary for loading operations on STONE I, and the master therefore proceeded to the berth as planned. During loading operation it was common practice that the officer on watch went to the bridge to read the wind speed on the anemometer to monitor the weather conditions.

Weather criteria and observed wind

Upon arrival at the jetty, the terminal´s ship-shore safety checklist was completed. According to the ship-shore safety checklist, the maximum wind criteria for operation had been agreed on before loading operation commenced (figure 10).

48. The maximum wind and swell criteria for operation have been agreed. *Grænser for max vindhastighed og strøm under operationen er aftalt.*			A	Stop cargo: 20 m/s wind speed Disconnect: 22 m/s wind speed Unberth*: 24 m/s wind speed * Only with acceptance from chief pilot

Figure 10: Extract from the terminal´s ship-shore safety checklist
Source: Inter Terminals Denmark EOT Aps / DMAIB

According to the checklist, the loading operation was to be stopped, if the wind reached 20 m/s. It was not stated whether the wind criteria related to average or gust wind speed. During the investigation, the terminal informed DMAIB that the wind criteria in their checklist referred to an average wind speed, defined as the average wind speed measured within a period of ten minutes. Hence, the wind criteria allowed for continuation of the loading operation though the wind gusts exceeded 20 m/s, as long as the average wind speed was not exceeded within the 10 minute period.

On figure 11 next page, a record of wind direction and speed from Ensted Oil Terminal is presented. It shows wind measurements and trend data for the average wind speed for the period 0800-1000 on 4 January 2020. STONE I's mooring winches started to pay out at 0929. In the period of 0927 to 0940, the wind data shows a sudden increase in wind speed up to 25 m/s and a change of wind direction from 270° to 325 °. This wind speed was higher than the forecast predicted. However, the average wind speed did not at any time during the time period exceed the terminal's wind criteria for loading.

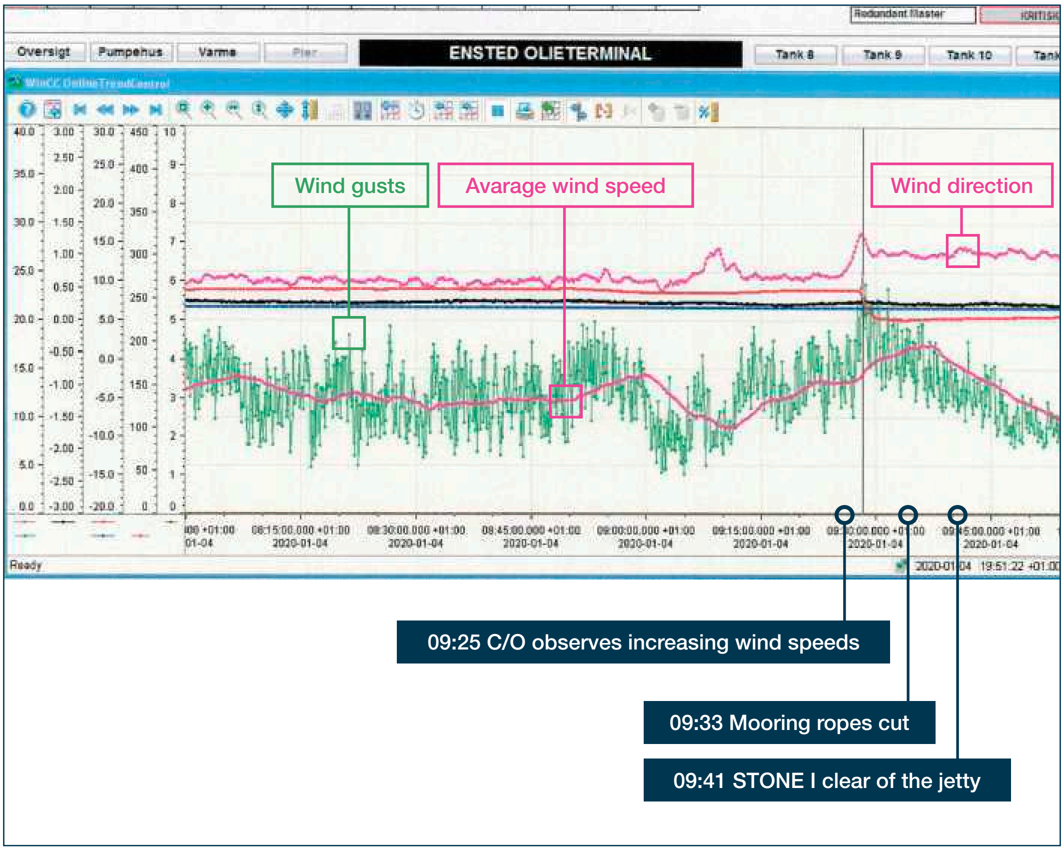


Figure 11: Screendump from Inter Terminals' trend control panel
Source: Inter Terminals Denmark EOT Aps/DMAIB

Wind force acting on the ship

During the accident STONE I was berthed port side alongside, heading 080°, and the wind came from a WNW direction. The wind hence acted on the ship's aft on port side, where the ship's accommodation was located (figure 12, next page). The wind direction and location of the accommodation exposed the aft part of the ship to a higher lateral force than on the forward, which caused a higher the load on the aft moorings than on the forward.

The owner of the terminal contracted FORCE Technology to calculate at what wind force the winch brakes would release. The report prepared by FORCE concluded that the ship should not suffer from collapse of the winch holding capacity for wind speeds below 31 m/s for any wind direction. This finding implies that the winches had not been correctly applied or malfunctioned. However, the report contained several uncertainties. E.g. the pretension of the moorings and the mooring ropes vertical angles were not included in the calculation. These are significant factors for determining the load on the winches.

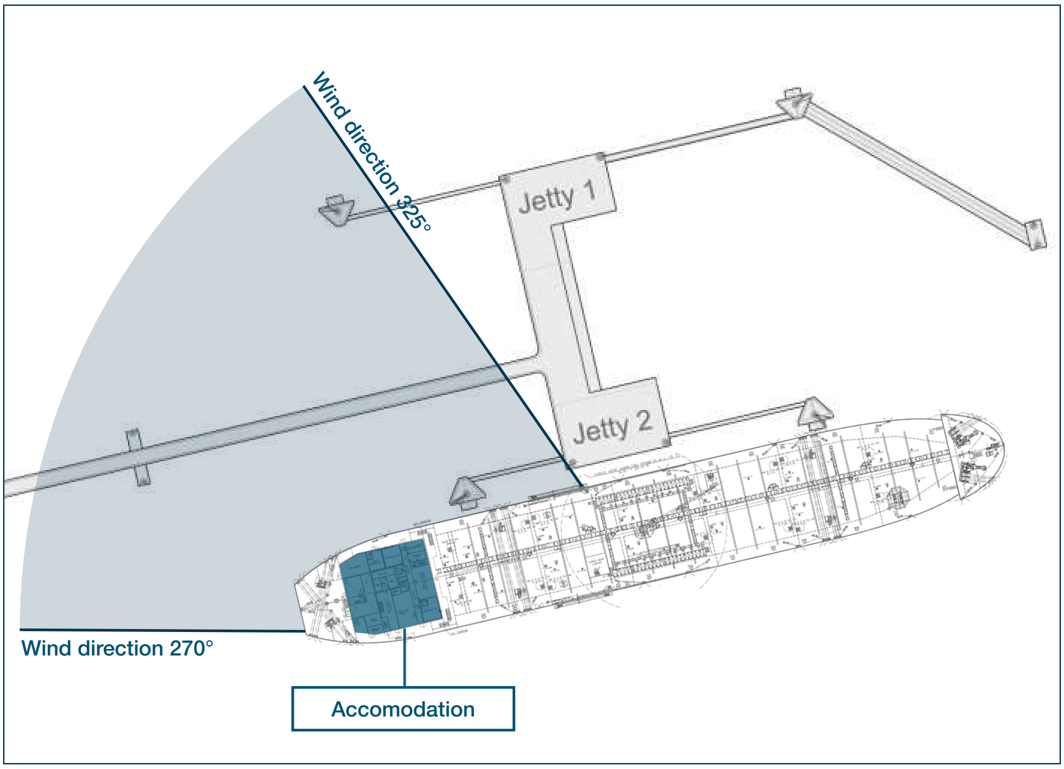


Figure 12: Wind forces acting on the ship during the accident
Source: Inter Terminals Denmark EOT / Zenith Gemi Isletmeciligi AS / DMAIB

Findings

- The mean wind did not exceed wind criteria that the terminal and ship had agreed.
- The wind gusts exceeded the forecast received by the ship.
- The wind direction and location of the accommodation exposed the aft part of the ship to a higher lateral force than on the forward.

Mooring arrangement on STONE I

Mooring layout

STONE I had four mooring stations: one aft, two on the main deck and one on the forecastle. On the aft mooring station, the mooring fittings consisted of two double drum mooring winches, Panama fairleads, bollards and pedestal rollers. Both winches had two specific fairleads allocated in each side of the ship to which the mooring lines could be led directly. The pedestal rollers could not be used for directing mooring lines from the winches to any other fairlead, because they were not aligned with the tension drum on the winches. The pedestal rollers were aligned with the winch head and were thus meant to be used for tightening loose mooring lines or bringing towing lines on board through the centre fairlead. It was only possible to use the centre fairlead for loose mooring lines or towing lines (figures 13 and 14, next page).

The two mooring stations on the main deck had a similar layout. On each of the mooring stations, the mooring fittings comprised two single split drums, fairleads and bollards. The winches were located on each side of the ship and had one designated fairlead in each side of the ship. The bollards also had designated fairleads in each side. It was not possible to use the bollards for loose mooring lines, as there were no aligned winches to tighten the lines (figure 15, next page).

Figure 13: Mooring arrangement aft deck
Source: DMAIB

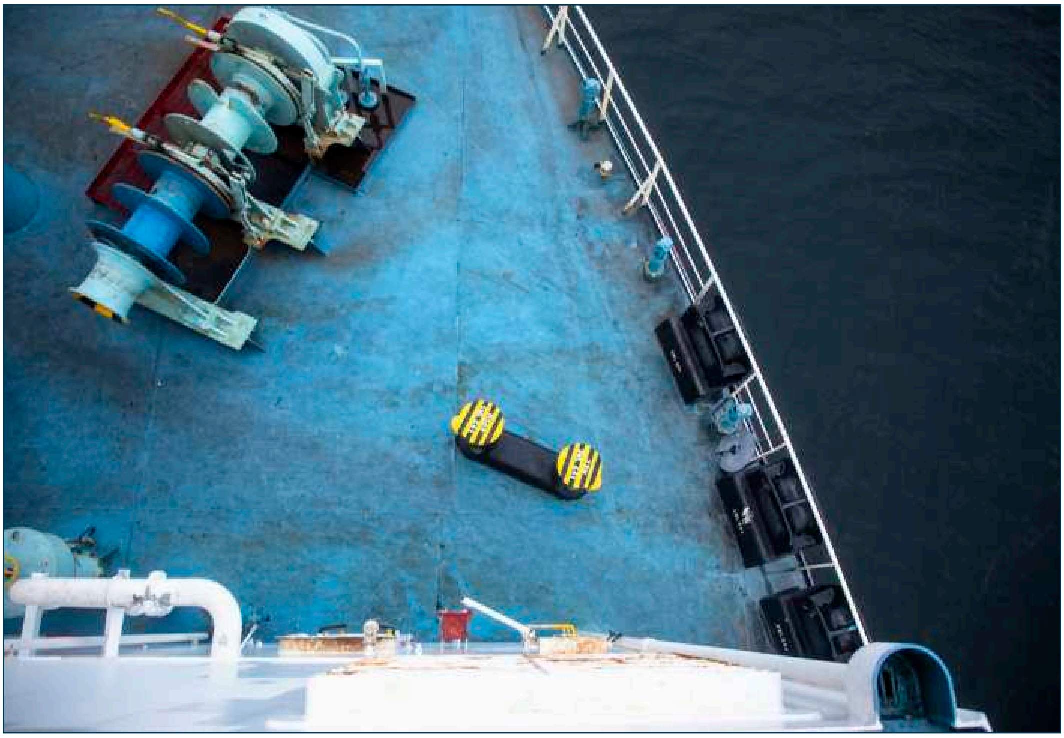


Figure 14: Mooring arrangement aft deck port side
Source: DMAIB

Figure 15: Mooring arrangement on the main deck
Source: DMAIB

On the forward mooring station, the mooring fittings on the forecastle comprised two double drum mooring winches, bollards, pedestal rollers and fairleads. Both winches had two specific fairleads allocated in each side of the bow to which the mooring lines could be led directly. The pedestal rollers could not be used for directing mooring lines from the winches to any other fairlead, because they were not aligned with the tension drums on the winches. The pedestal rollers were aligned with the winch heads and were thus meant to be used for tightening loose mooring lines or bringing towing lines on board through the centre fairlead and designated fairleads in port and starboard sides.

From a review of the general arrangement it was noted that the bollards located near the centre fairlead were symmetrically placed, however on the ship they were not. Additionally, two pedestal rollers were placed on portside, which did not appear on the general arrangement. It was only possible to use the centre fairlead for loose mooring lines or towing lines (figures 16 and 17).

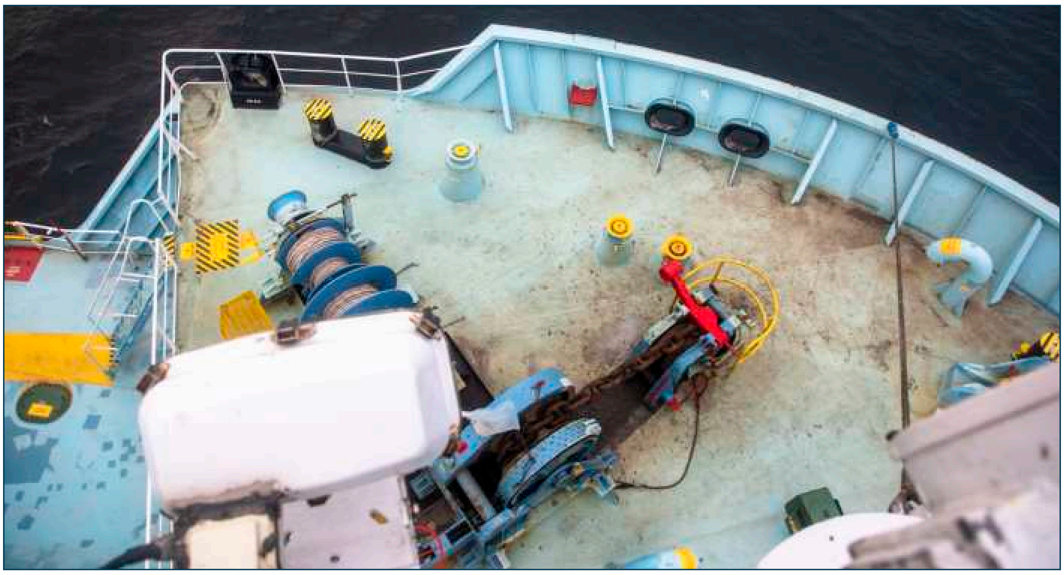


Figure 16: Mooring arrangement forecastle port side
Source: DMAIB

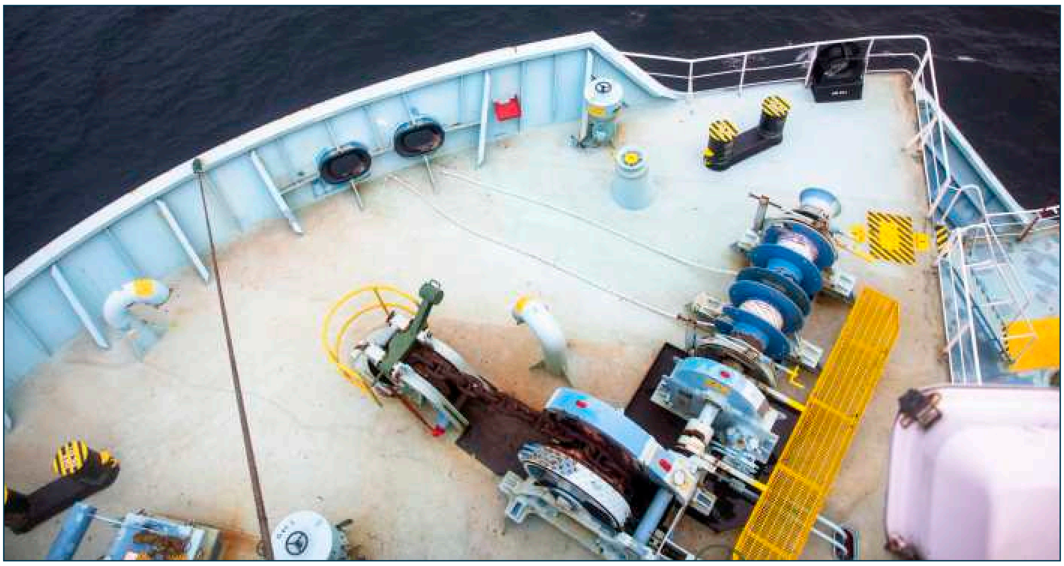


Figure 17: Mooring arrangement forecastle starboard side
Source: DMAIB

The illustration below shows the possible ways of directing mooring lines on STONE I, when the ship was portside alongside. It is noted that on the aft mooring station the mooring layout did not allow for mooring lines to be directed from the winches to the berth via the transom (figure 18).

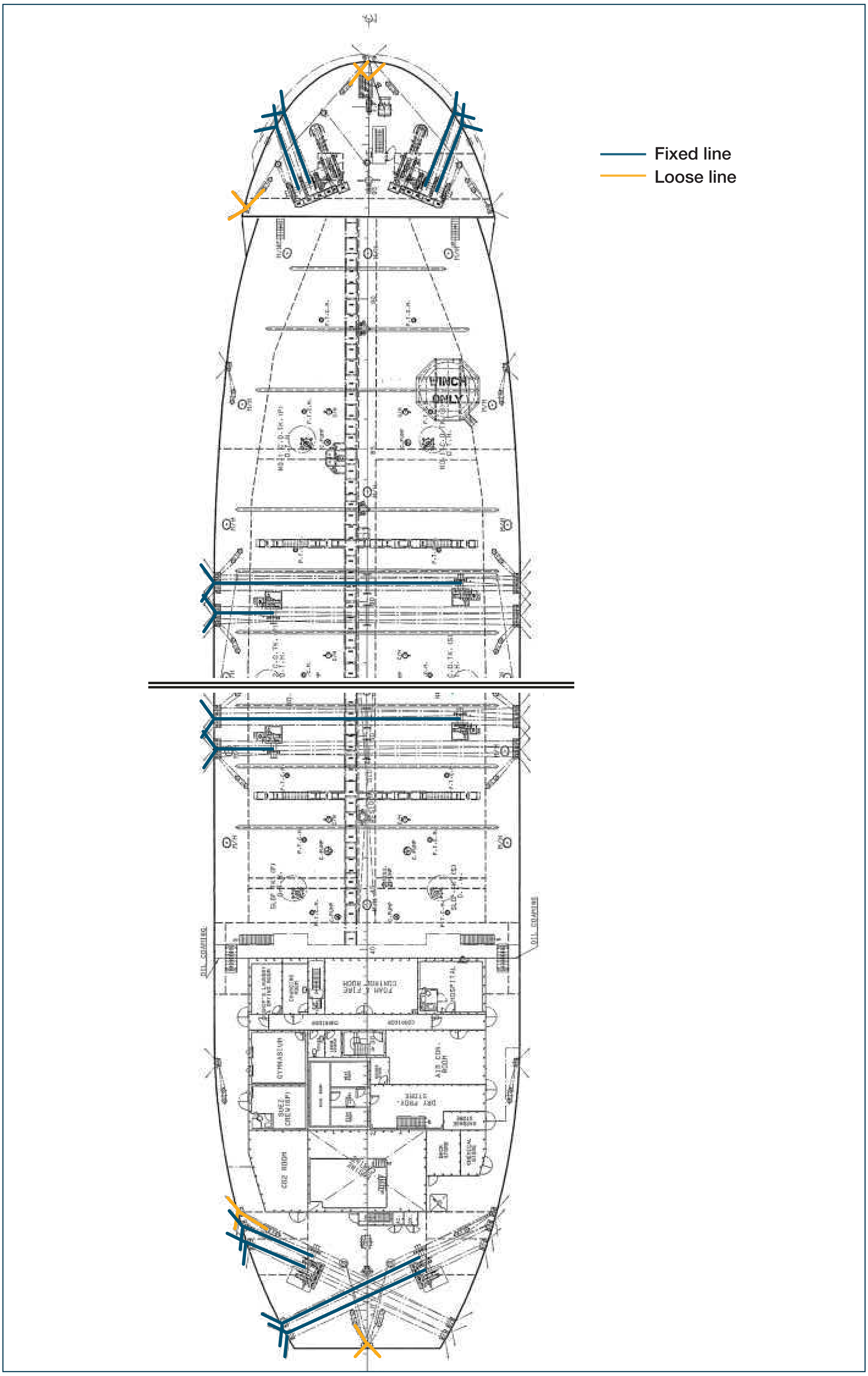


Figure 18: Possible ways of directing mooring lines on STONE I when berthed on port side. Source: Zenith Gemi Isletmeciligi AS / DMAIB

Mooring management plan

The design of the ship's mooring arrangement was based on OCIMF´s mooring equipment guidelines that met OCIMF standard environmental criteria. Mooring restrain calculations to determine the strength and number of mooring lines and winches had been carried out by the shipyard during the design stage of the ship. According to the ship's mooring management plan, STONE I was designed to account for standard mooring patterns and allowed flexibility to meet alternate mooring patterns.

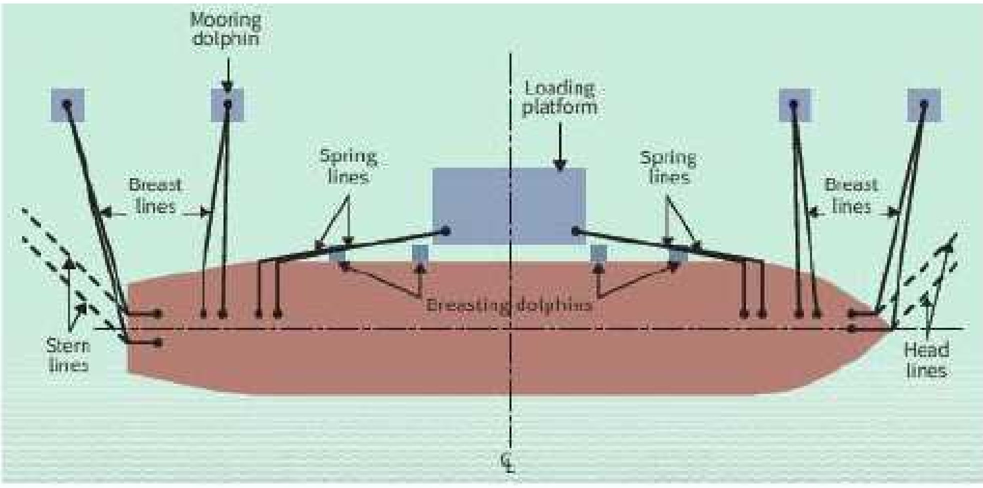
The ship's initial mooring philosophy was based on a typical mooring pattern, which is shown in figure 19 below.

OCIMF standard environmental criteria

60 knots wind from any direction simultaneously with:

3 knots current at 0 or 180
or
2 knots current at 10 or 170
or
0.75 knots current from the direction of maximum beam current loading.

Source: OCIMF, Mooring Equipment Guidelines.



Vessels Up to 38000 DWT	Vessel more than 38000 DWT
2 Head / Aft Lines	2 Head / Aft Lines
2 Breast Lines	4 Breast Lines
2 Spring Lines	2 Spring Lines

Figure 19: Mooring philosophy according to the mooring management plan
Source: Zenith Gemi Isletmeciligi AS / DMAIB

The mooring pattern described in STONE I´s mooring management plan was based on OCIMF´s mooring equipment guidelines, which described that the mooring lines should be as symmetrical as possible about the amidships point of the ship. Breast lines should be oriented as perpendicular to the longitudinal centre line of the ship and positioned as far aft and forward as possible. Spring lines should be oriented as parallel as possible to the longitudinal centre line of the ship. The vertical angle of the mooring lines should be kept to a minimum.

The mooring philosophy in the mooring management plan stated the principles for the optimal mooring pattern of tankers. However, the mooring management plan recognised the fact that an optimal mooring pattern was not always achievable, e.g. due to mooring hooks, mooring dolphins or mooring winches being out of service, or if breast lines could not achieve the optimal perpendicular lead. According to the mooring management plan, it was the master´s responsibility to utilise these alternate arrangements at his discretion in such situations, considering the prevailing environmental conditions. In the event of deteriorating weather or sea conditions, the mooring management plan stated that the master should not hesitate to put out extra moorings, if he considered this to be necessary, and that weather forecasts, tide tables and unpredicted changes in environmental conditions should be monitored closely while at berth, in order to avoid the vessel breaking out from its berth.

Findings

- The aft mooring station did not allow for mooring lines to be directed from the winches to the berth via the transom.
- The mooring management plan recognised that an optimal mooring pattern was not always achievable.
- In the event of deteriorating weather or sea conditions, the mooring management plan stated that the master should not hesitate to put out extra moorings, if he considered this to be necessary.

Mooring layout at Ensted Oil Terminal

Ensted Oil Terminal is located in Aabenraa fjord. The terminal and the jetties were built in 1979 to accommodate tankers and bulk carriers up to 300,000 tons. The terminal was projected in a south-westerly and north-easterly direction. The terminal has two jetties (figure 20). Jetty 1 faces north and was designed to accommodate vessels from 70,000-300,000 DWT. Jetty 2 faces south and was designed to accommodate vessels from 6,500 to 120,000 DWT. The two jetties are connected to land via a service road. A terminal control room is located at the loading platform at jetty 2. Terminal operators monitored the loading from the control room on the jetty. Due to the geographic location with coastal open structure jetties, the jetties were exposed to weather forces, especially wind.

Due to the ship's size, STONE I berthed at Jetty 2. Jetty 2 had 14 mooring hooks (figure 20, next page). Jetty 2 was fitted with two loading arms. When berthing the ship, the jetty's loading arms determined the position of the ship, as these needed to be aligned with the ship's manifolds. When the loading arms and manifolds were aligned, the possibilities for mooring the ship depended on the interface between the ship and the jetty and their available mooring equipment.

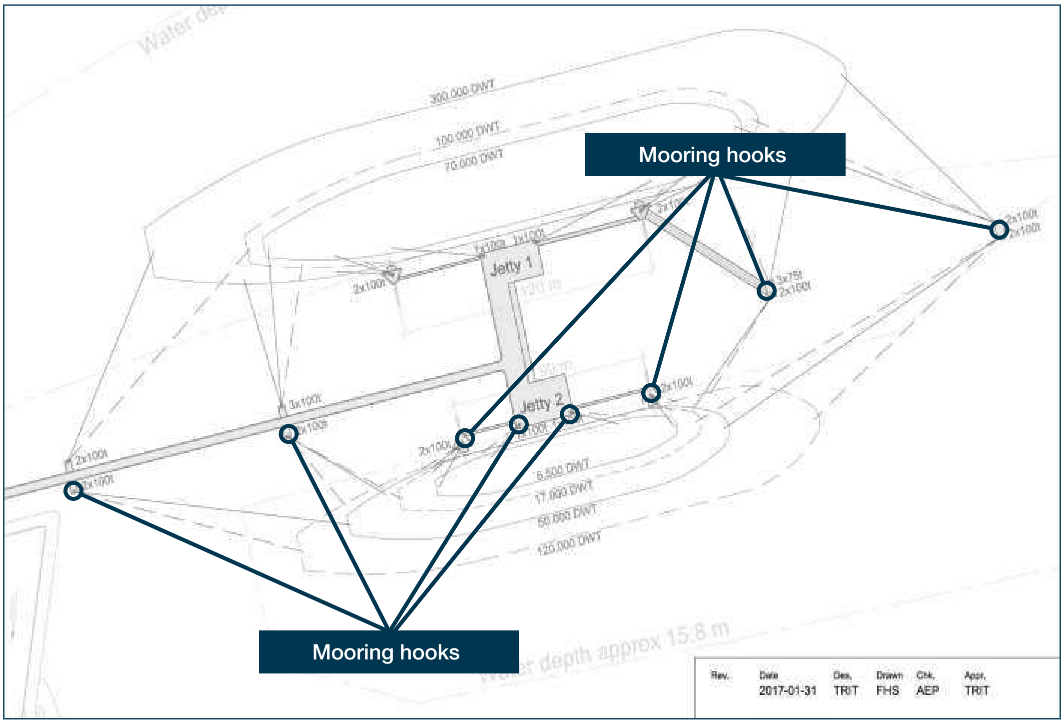


Figure 20: Ensted Oil Terminal mooring plan
Source: Inter Terminals Denmark EOT Aps / DMAIB

Finding

- The alignment between the jetty's loading arm and the ship's manifold determined the mooring configuration options.

Mooring configuration during the accident

Prior to arrival at Ensted, the master and pilot planned the mooring configuration. The plan was documented in a form from the ship's safety management manual (Master Pilot Information Exchange, figure 21)

The agreed mooring configuration was similar to the typical mooring pattern in the ship's mooring management plan. However, during berthing, the master was informed that the jetty's bollards and hooks were not aligned to direct the breast lines in an optimal angle. The master assessed the situation and decided to accept the mooring configuration as this seemed to be the only feasible option. STONE I was thus moored with four lines on the forecastle, four lines on the main deck and four lines on the aft (figure 22).

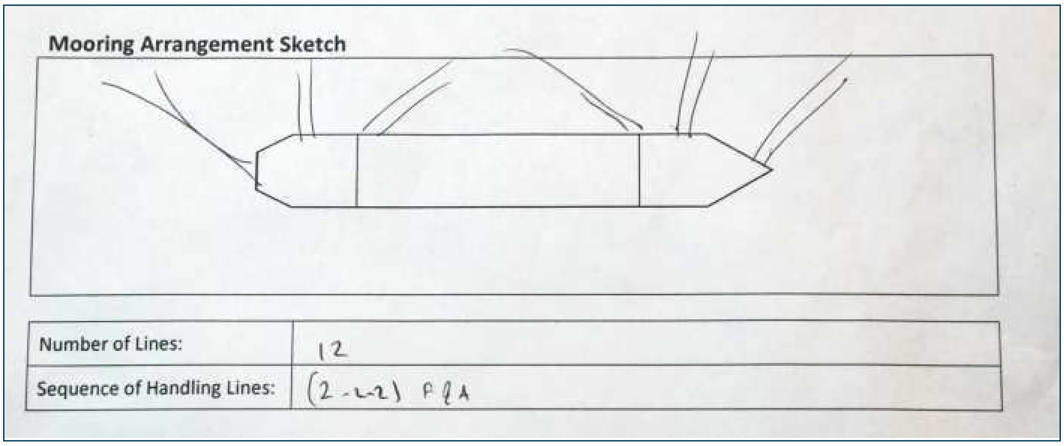


Figure 21: Mooring philosophy according to the mooring management plan
Source: Zenith Gemi Isletmeciligi AS / DMAIB

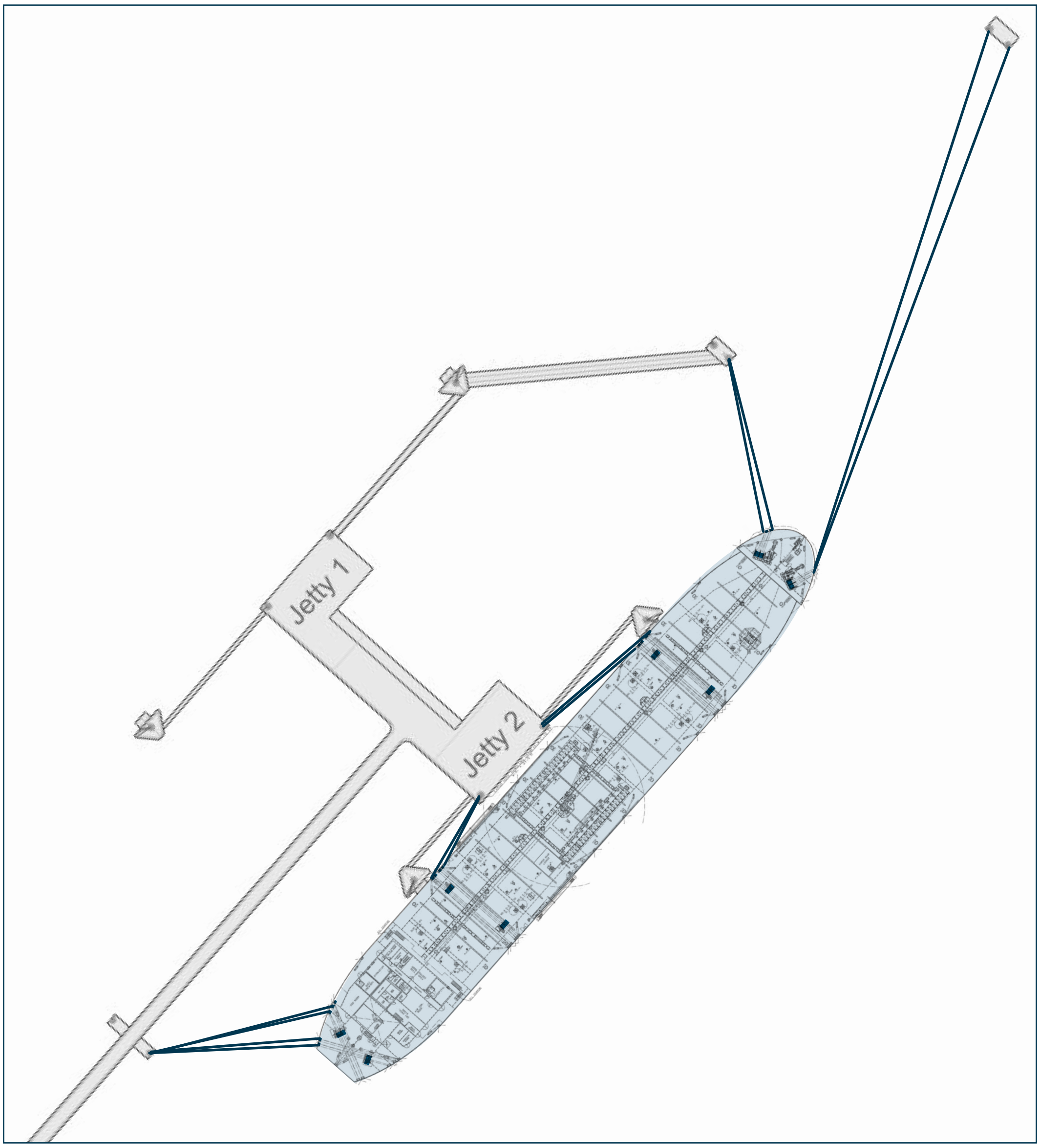


Figure 22: STONE I moored at Ensted Oil Terminal
Source: STONE I

An examination of the actual mooring configuration on STONE I at Ensted showed that it differed from the mooring configuration, which the master had initially planned, from the mooring pattern described in the ship's mooring management plan and from Ensted Oil Terminals' mooring plan. The main difference was that the intended breast lines on the aft deck had an angle of approx. 35° instead of the ideal 90°. In comparison, the stern lines had an angle of 50 approx., and was hence leading in a more perpendicular direction than the breast lines (figure 23).

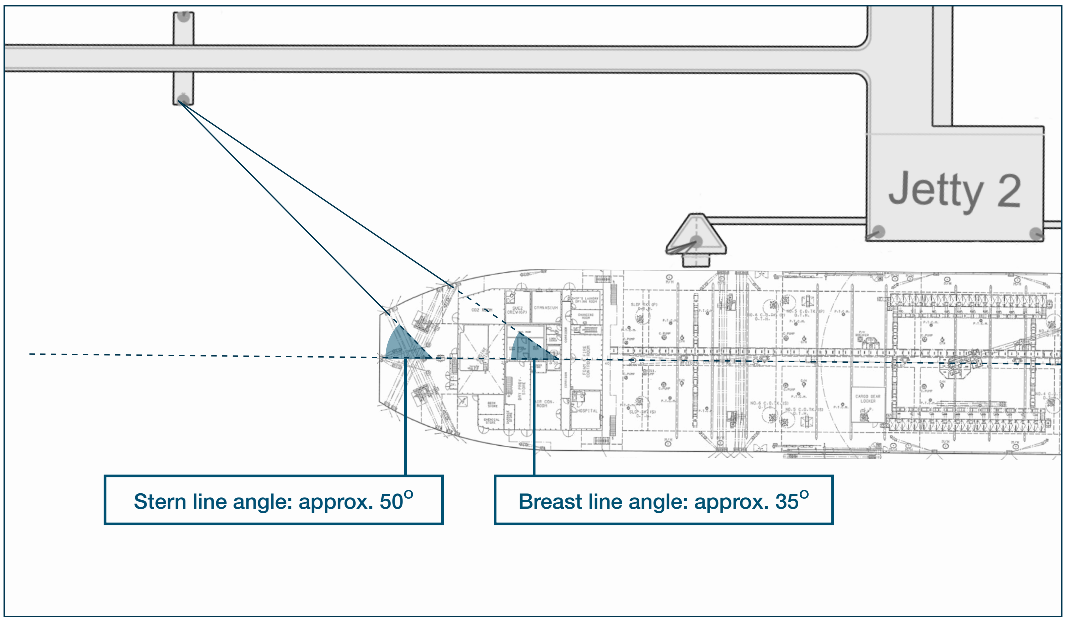


Figure 23: STONE I moored at Ensted Oil Terminal
Source: STONE I

Findning

- On the aft part of STONE I, the mooring configuration on the day of the accident diffe-red significantly from the planned.

Analysis

Analysis of the accident

The aim of the investigation was to establish why STONE I's mooring winches gave way during a brief hailstorm, causing the ship to drift uncontrollably from the jetty at Ensted Oil Terminal. The winches' restrain capacity, the wind forces acting on the ship and the mooring configuration between the ship and jetty were therefore examined.

During the investigation it was concluded that the winch brakes did not mechanically malfunction. The remaining contributing factors that could have influenced the restrain capacity of the winches were therefore the application of the winch brakes, the mooring configuration and the wind conditions. It was not possible to reconstruct the exact mooring situation. Hence, important data was unavailable for the investigation, which introduced uncertainties for establishing the cause of the accident. Instead, the contributing factors were investigated individually to assess how they plausibly could affect the winches restrain capacity.

Application of winch brakes

As the mooring lines had been pretensioned, and the brakes developed smoke and noise, it could be concluded that the winch brakes were applied. However, it was not possible to determine whether they were fully applied. The visual indicators on the winch brakes' threaded rod left little discretionary space for how much force to apply on the hand wheel. As the brake had been tensioned and the brake tensioning left little possibility for maloperation, DMAIB found it most plausible, that the brakes were fully applied on the winches. However, the possibility of partial brake tension on any of the individual winches cannot be excluded.

Mooring configuration

The planned mooring configuration was changed when the ship was berthing, because the ship's mooring layout and the layout of the jetty did not allow for the ship to be fastened with breast lines perpendicular to the jetty. The mooring configuration on the day of the accident differed from the one planned in various ways, most importantly the aft breast lines being led significantly aft.

The actual mooring pattern and the direction of the mooring lines from the aft deck had the effect that the aft moorings had significantly reduced transverse restrain capacity. This resulted in an increased load on the aft mooring winches. When the wind force suddenly increased, the wind direction and location of the accommodation exposed the aft part of the ship to a higher lateral force than on the forward. This added an increased load on the aft mooring winches.

DMAIB finds it plausible that these two factors in combination caused a load to the aft winches to the extent that winches exceeded their brake holding capacity, and the mooring winches payed out. However, it was not possible to reconstruct the exact circumstances of the mooring situation at the time of the accident. It has therefore not been possible to make precise calculations on the forces acting on the winches.

Acceptance of an alternative mooring configuration

As acknowledge by the ship's mooring management plan, situations will arise in which it is impossible to achieve the optimal mooring configuration, and in such situations, it is within the master's discretion to assess and choose other options.

When master during berthing was informed that it was not possible to achieve the planned mooring configuration, he had to make a decision to adapt to the situation, keeping in mind that it was not an option to cancel the berthing of the ship under the given circumstances. The combination of the ship's mooring layout, the jetty's layout and the alignment between the jetty's loading arms and the ship's manifolds made it impossible to fasten the aft breast lines in any other way than leading them significantly aftwards. Based on an assessment of the alternative mooring configuration's holding capacity against the forecasted weather, the master accepted the situation. Neither the terminal employees, the ship's crew nor the pilot found any reason to call the configuration into question, and no problem was experienced with the holding capacity of the mooring configuration, until the weather suddenly deviated from the weather forecast.

Conclusion

Conclusion on the investigation

On 4 January 2020 STONE I drifted uncontrollably from the jetty at Ensted Oil Terminal as an unexpected hail storm occurred and a short forceful increase in wind speed acted on the ship. The ship immediately started to drift when the mooring winches' brake load capacity was exceeded and started to pay out the aft mooring lines.

The ship had a mooring configuration different from the planned, which reduced the aft winches transverse restrain capacity. Though recognised by the crew as not optimal, the actual mooring configuration was assessed to be sufficient for the forecasted weather and was not called in to question by the ship's crew, pilot and terminal employees. When the weather unexpectedly changed and a sudden increase in wind force started to act on the ship, the inexpedient angle of the four aft lines caused a load on the mooring winches, which exceeded their brake load capacity. While the alternative mooring configuration was sufficient for the forecasted weather conditions, it did not render sufficient restrain capacity for the sudden change in weather conditions experienced on the day of the accident. Instrumental for the accident was thus the acceptance of that less than optimal method of mooring, which was driven by the necessity of berthing the ship and the absence of alternative mooring options.

The ship's crew and terminal employees monitored the weather during the loading operation in order to react, if the weather conditions unexpectedly worsened. When the wind started to act on the ship, the crew on STONE I initiated the emergency stop for loading, but within a few minutes the ship drifted from the jetty and the loading arms broke off. The rate at which the wind speed increased did not render sufficient time for the ship's engines to be ready for manoeuvring or for the terminal to finalise the emergency stop procedure.

Emergency preparedness on board and on shore was based on monitoring a progressive increase in wind speed which would render sufficient time for initiating emergency measures in case of sudden changes in the wind. However, on the day of the accident, the change in weather conditions did not develop progressively, and once it was apparent that the wind speed limit was reached, it was too late to avoid the drifting of the ship and the subsequent oil spill.

Appendix

SHIP PARTICULARS

Name of vessel:	STONE I
Type of vessel:	Chemical/oil products tanker
Nationality/flag:	Marshall Island
Port of registry:	Majuro
Call sign:	V7HX5
IMO no.:	9380582
DOC company:	Zenith Gemi Isletmeciligi AS
IMO company no. (DOC):	5738734
Classification society:	DNV-GL
Year built:	2008
Shipyard/yard number:	Zenith Gemi Isletmeciligi AS
Overall length:	184,32 m
Breadth overall:	27,40 m
Draught max.:	11,52 m
Gross tonnage:	23248
Engine rating:	9480 kW
Service speed:	14,20 knots
Hull material:	Steel
Hull design:	Double hull

VOYAGE DATA

Port of departure:	Hamburg, Germany
Port of call:	Ensted Oil Terminal, Aabenraa, Denmark
Type of voyage:	International
Cargo information:	Ballast
Manning:	23
Pilot on board:	Yes

WEATHER DATA

Wind – speed, direction:	25 m/s - NW
Visibility:	Moderate
Weather conditions:	Hail storm
Light/dark:	Light

MARINE CASUALTY INFORMATION

Type of marine casualty:	Loss of control
IMO classification:	
Date, time:	4 January 2020
Location:	Ensted Oil Terminal, Aabenraa, Denmark
Position:	55°04,1N - 009°27,4E
Ship's operation:	Loading operation
Human factor data:	Yes
Consequences:	20 m3 gas oil was spilled on to the ship's deck and 3-5 m3 into the sea.. Indents to ship's plating below waterline and damages to the ship's manifold and hose railing. Terminal's loading arms damaged. No injuries to persons.

SHORE AUTHORITY INVOLVEMENT AND EMERGENCY RESPONSE

Involved parties:	Municipal fire and rescue service South Jutland, Danish Police, Danish Home Guard.
Resources used:	DIANA P520, MARIE MILJØ, MHV910 RINGEN
Speed of response:	20 minutes.
Actions taken:	Oil containing equipment deployed at sea and ashore.
Results achieved:	Oil contained.

RELEVANT PERSONS

Master:	38 years old. 14 years of experience at sea. 3 months on STONE I. Certificate STCW- II/2 as Master.
Chief officer:	29 years old. Had served on STONE I for 1.5 months. Certificate STCW- II/2 as Master.