Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry
of Transport and Digital Infrastructure

Investigation Report 421/18

Less Serious Marine Casualty

Occupational accident on board the MV SVENJA at the pier in the port of Rostock on 31 October 2018

18. June 2020

This investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG). According to said Law, the sole objective of this investigation is to prevent future accidents. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

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1 SUMMARY

At about 1930[1] local time on 31 October 2018, an occupational accident occurred at the pier in the port of Rostock when a monopile (MP) weighing 814 t fell onto the pier and a ship. One person suffered minor injuries during the accident.

[1] All times shown in this report are Central European Time (CET) = UTC + 1 hour.

2 FACTUAL INFORMATION

2.1 Photograph of the ship

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Figure 1: Photograph of the ship

2.2 Ship particulars

Name of ship:	SVENJA
Type of ship:	Motor vessel, heavy lift carrier
Flag:	German
Port of registry:	Hamburg
IMO number:	9458901
Call sign:	DIJA
Owner (according to Equasis):	SAL Heavy Lift GmbH
Owner:	SAL Ship Management UG & Co. KG
Year built:	2007
Shipyard:	J.J. Sietas KG, Yard Number 1279
Classification society:	DNV GL
Length overall:	160.50 m
Breadth overall:	27.91 m
Draught (max.):	9.00 m
Gross tonnage:	16,026
Deadweight:	12,975 t
Engine rating:	12,600 kW
Main engine:	MAN 9L 58/64
(Service) Speed:	18 kts
Hull material:	Steel
Hull design:	Double bottom

2.3 Voyage particulars

Port of departure:	Rostock
Port of call:	Sea transport
Type of voyage:	Merchant shipping/ international
Cargo information:	MP transport
Manning:	25
Draught at time of accident:	Fore: 8.60 m. Midships: 8.65 m. Aft: 8.70 m
Pilot on board:	No
Canal helmsman:	No
Number of passengers:	None

2.4 Marine casualty or incident information

Type of marine casualty:	Less serious marine casualty
Date, time:	31/10/2018 at about 1930
Location:	
Latitude/Longitude:	φ 54° 09'N λ 012° 07.4'E
Ship operation and voyage segment:	Made fast alongside harbour jetty
Place on board:	On deck and ashore
Human factors:	Yes
Consequences:	One seaman slightly injured (bruises), total loss of MP and damage to the ship, quay and SPMT[2]

Extract from Navigational Chart BSH 3005, Sheet 1

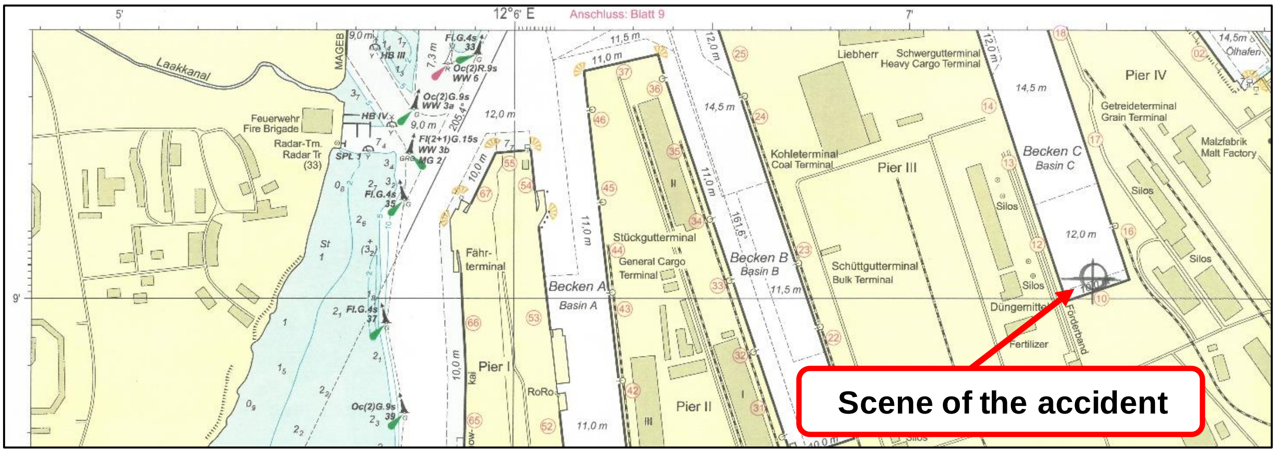

Figure 2: Navigational chart

2.5 Shore authority involvement and emergency response

Agencies involved:	Waterway police (WSP)
Resources used:	Crane
Actions taken:	Casualty taken to hospital and ship secured

[2] SPMT: **S**elf-**p**ropelled **m**odular **t**ransporter.

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

On 31 October 2018, the SVENJA was moored according to regulations on her port side at Berth 10 in the port of Rostock. Six wind turbine MPs were scheduled for loading with her own heavy lifting tackle. Crane 2 aft was carrying out the final lift (MP A28) in single-crane operation. The MP was lifted from the SPMT slightly diagonally at 1900 and then swung over MP E24, which was already on board. At about 1932 (the ship was almost upright and the crane about 45° above MP E24), MP A28 tilted toward the shore and began to slip out of the slings. MP A28 first fell onto MP E24, which was already stowed, then onto the quay wall and pushed the ship away from the quay wall on the port side and into the quay wall aft in the process. At the same time, some of the mooring ropes parted and the gangway attached at the front fell off the quay wall.

3.2 Investigation

The BSU was notified of the accident at 1511 on 1 November 2018 and the first survey was made on 2 November 2018. During the survey one end of the MP lay on the pier and the other on the ship, which was moored at the bow with new lines. The cranes had been turned lengthwise, Crane 2's traverse was detached and the SPMT already removed. At the stern, the ship was wedged against the pier and additionally made fast with mooring lines/cables.

Figure 3: Scene of the accident on 2 November 2018

Figure 4: MP A28 seen from the pier

Figure 5: Ship wedged at the stern

3.2.1 Ship operation

The heavy lift carrier SVENJA has two cranes, each with a SWL of 1,000 t[3]. She transports offshore wind turbine MPs from Rostock to Teesport in England for the Hornsea offshore wind farm construction site, which is in the North Sea off Great Britain. Prior to this accident 138 MPs had been transported (75 by two cranes and 63 by one crane). After ten MP lifting operations with only one crane, a rope was in the conical section. The crane gear is certified every six months and tested regularly. The same gear is used each time and only the configuration varies due to differing MPs with stowage cradles and attachments.

3.2.2 Configuration of the cargo gear

The cargo gear consists of a traverse (green), which is 16 m in length and suspended from the crane hook with wire ropes (blue). Depending on the MPs being moved, two Dyneema ropes/slings (orange) of about 27 m in length are attached to one end of this traverse with a wire rope (blue). The maximum distance between the slings is 16 m (see below example of the cargo gear).

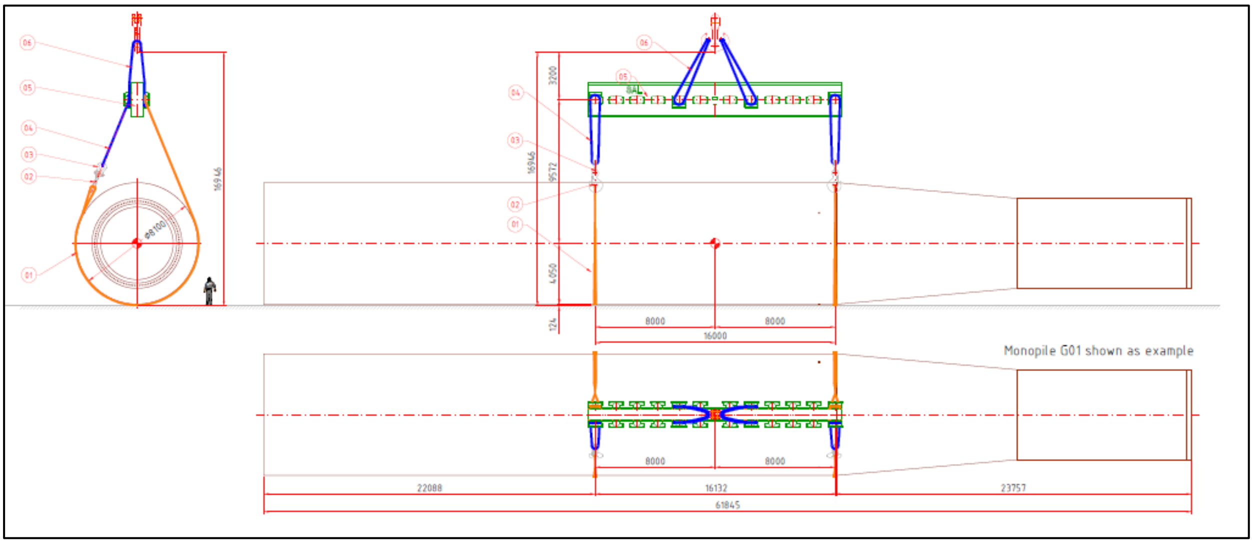

Figure 6: Configuration of the loading gear (overview)

[3] SWL: Safe working load.
WLL (working load limit) is the newer designation.

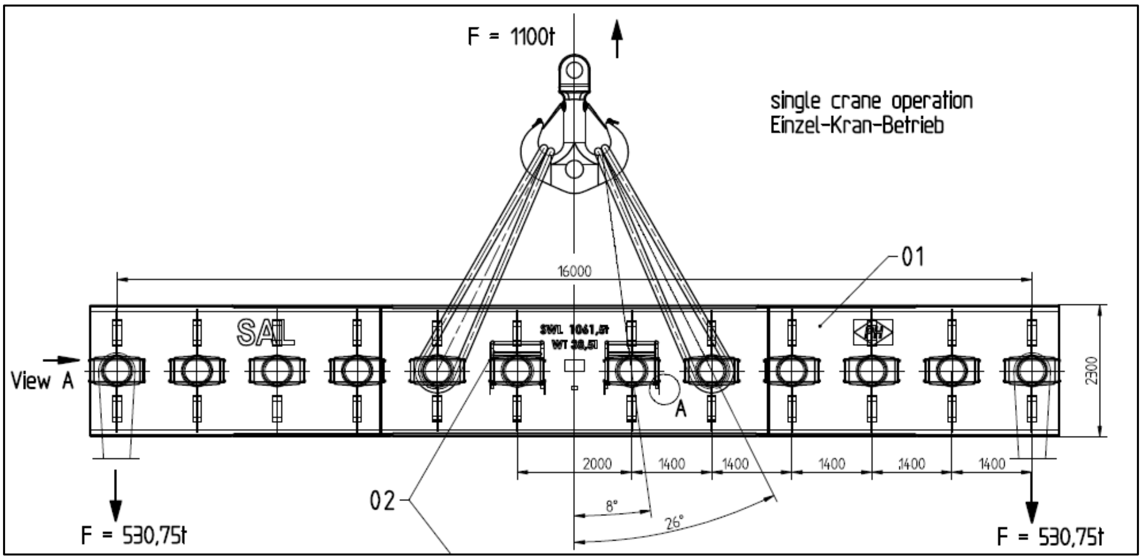

Figure 7: Traverse in single-crane operation

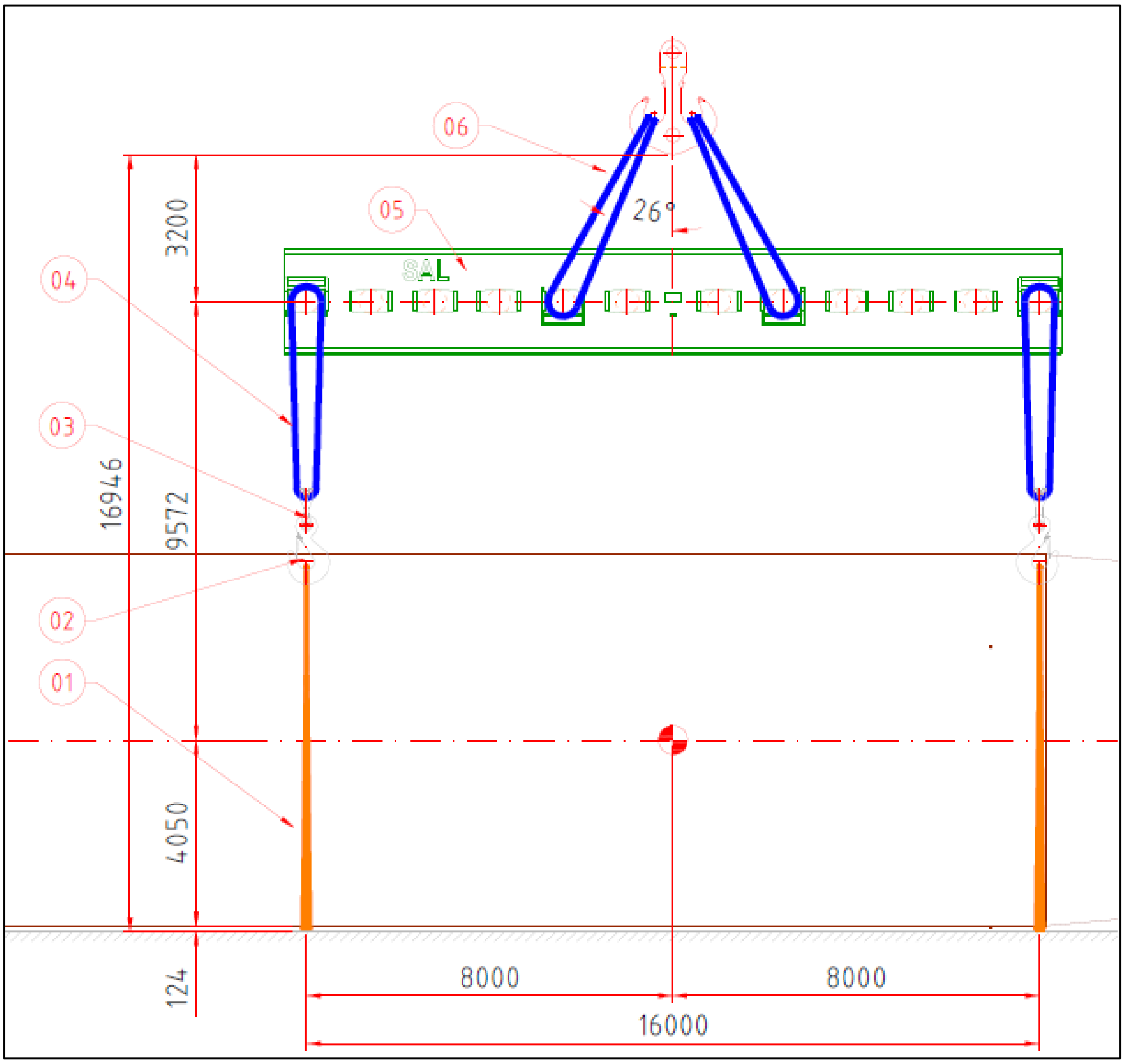

Figure 8: Centroidal distance

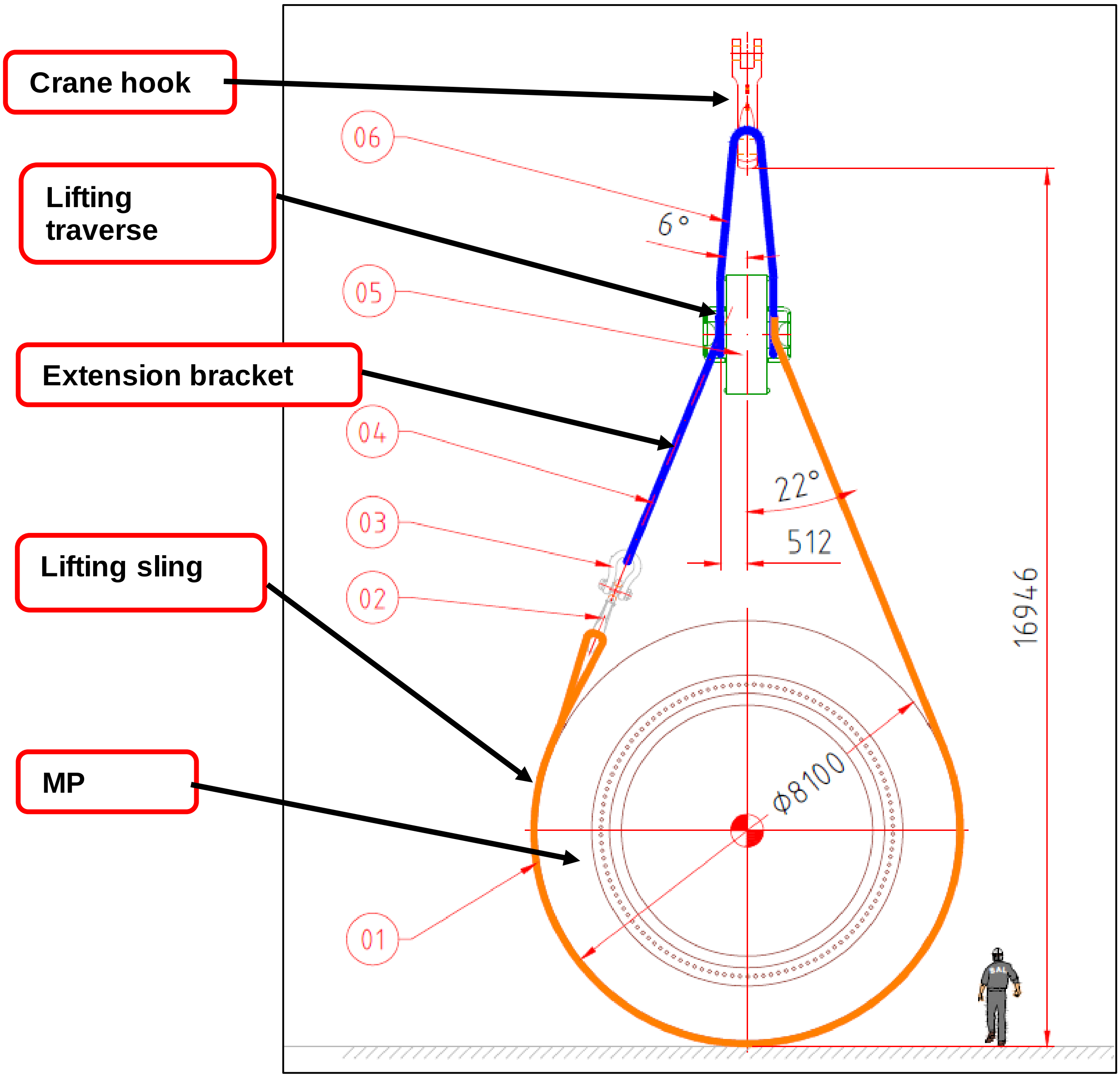

Figure 9: MP enlacement

New Dyneema ropes and protective sleeves were used for loading on the day of the accident. The protective sleeves are designed to prevent the slings from causing abrasion damage to the MPs. The new slings were load tested at a company (Seil-Hering) in Hamburg in the presence of a project engineer from DNVGL before deployment on the ship. It was the sixth time the new slings had been used for lifting when the accident happened. The MPs from the first and second lift were placed in the cargo hold by two cranes and those from the third and fourth lift on deck. Crane 2 aft did the fifth lift alone, during which MP E24 was lowered next to it with both slings on the deck. Similarly, during the sixth lift Crane 2 aft alone was to lift MP A28 over and lower it aft on the starboard side next to the already stowed MP E24. Unlike the previous lift, one sling was just in the conical part of the MP. The second officer marked the sling positions on the MP in accordance with the design specifications of the marked centre of gravity when it was still ashore on the SPMT (see Figures 10 and 11).

3.2.3 Crew

The ship, cranes and winches were sufficiently manned by experienced personnel. The lifting team consisted of the master, the chief officer, the second officer, as well as the first and second crane operators, who have been working together since 27 September 2018. 18 MPs were loaded during this period (12 by two cranes and six by one crane).

3.2.4 Environmental conditions and weather report

The Maritime Division of Germany's National Meteorological Service (DWD) was requested to prepare an official report on the weather conditions in the international port of Rostock for the period of the accident.
Weak south-easterly winds were recorded at the surrounding measuring stations during the period under consideration. It can therefore be assumed that mean winds of 3-6 kts prevailed at a height of 10 m above the waterline in the vicinity of the international port of Rostock. Observations made on the ground and radiosonde measurements indicate that gusts with a speed of at least 2 Bft more than the mean wind were unlikely.
The sky was very cloudy to begin with and later became overcast. No noticeable precipitation fell from clouds moving in from the south-west.

3.2.5 Loading operation

Loading did not start until about 1150 on 31 October 2018 because of the heavy wind and rain.
By 1830, two MPs had been loaded onto the hatch cover in tandem operation without a traverse and MP E28 with a traverse in single-crane operation.
Attachment of the ropes 16 m apart from one another to the traverse for lifting with one crane started at 1830. The chief officer had inspected the loading gear to ensure it was properly certified and approved it beforehand. The ropes were positioned at the markings measured from the centre of gravity (figure 8) according to the lift plan and the positions were checked after the ropes had been tensioned with a load of 20 t on the crane hook. The cables belonging to the two tugger winches were attached to the crane traverse for fixing and tensioned slightly.
Visibility was good with wind speeds of up to 3 m/s and there was no rain. Despite the darkness there was sufficient illumination from the cranes and the deck. There was also a searchlight on the observation deck, which could be used to check the condition of the winches.
After lifting started at 1900, MP A28 could be seen rising first at the conical end (front part) and then at the cylindrical end (rear part). A height difference of about 15-20 cm was observed, which was not considered critical, but normal.

The lifting operation was briefly paused after the MP was completely lifted off the SPMT and the slings were checked. During the slow lift/swing operation, without any break in the flow of work, the below Figures 10 and 11 were then taken. The cargo was lifted to a height at which it was possible to clear the three MPs already stowed by about 1.5-2 m. During this operation the tugger winches were used to tension the lines and align the load. The tugger winches were not used during the swing operation.

Figure 10: Lift before the swing operation

Figure 11: The swing operation

Crane 1 was swung toward the bank as a ballast counterbalance so as to maintain a maximum list of 0.5°. When Crane 1 was fully extended, the boom was lowered on the port side and following that only ballast water was used to correct the list.
The ship was almost upright and the raised cargo swung clear of the MPs already on board. At about 1932, MP A28's cylindrical part began to tilt toward the bank about half way between the quay and the ship when Crane 2 had turned about 45° over the ship. At this point the chief officer was situated starboard in the aft section of the hatch near the planned stowage position and the second officer was on the main deck in front of Crane 2's pedestal operating the tugger winches. It was noticed that the sling in the conical part first started to slip, that a stream of water was released under the MP and that the cylindrical end approached the crane's cabin. The MP slipped out of the slings toward the bank. When the MP dropped down, it first struck MP E24, which was already loaded, then it slipped toward the quay side and pushed the ship away from the quay. Apart from one head line, all the mooring lines at the bow parted and the gangway fell into the water at the front. Only a spring line parted at the stern and the ship became wedged against the quay wall aft.
The second officer was situated on the main deck near the crane during the accident and suffered minor injuries on his forearm due to falling parts.
At 1932 the general alarm was sounded and the entire crew was alerted.

Figure 12: Final position after the MP slipped

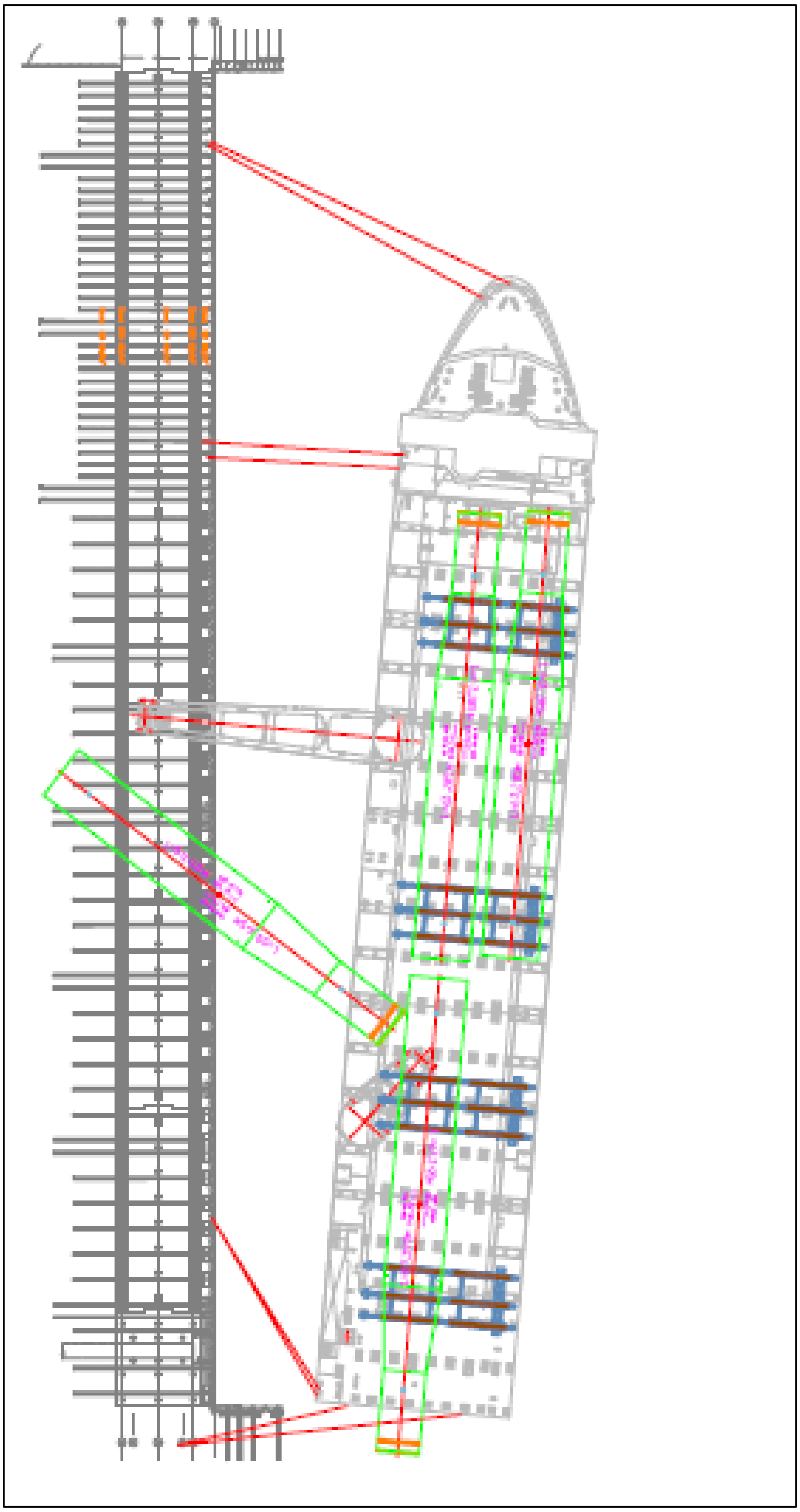

Figure 13: Final position of the ship and MP A28

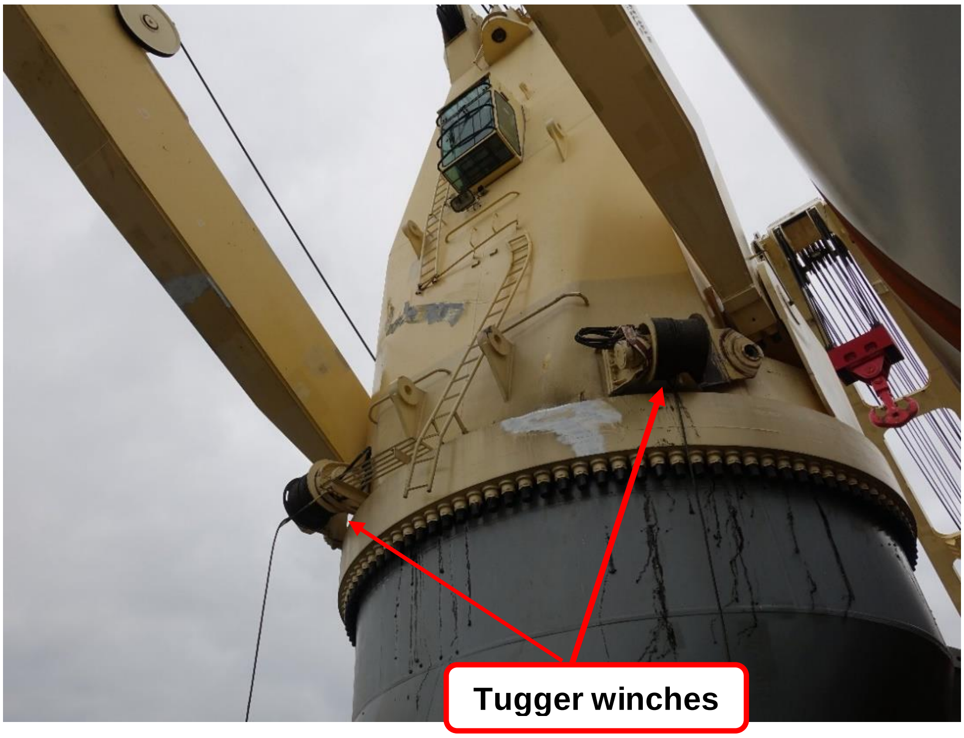

Figure 14: Damage to Crane 2

3.2.6 Lifting slings

When the BSU's investigators surveyed the SVENJA on 2 November 2018, the lifting traverse was stowed on deck with the two lifting slings in front of it.

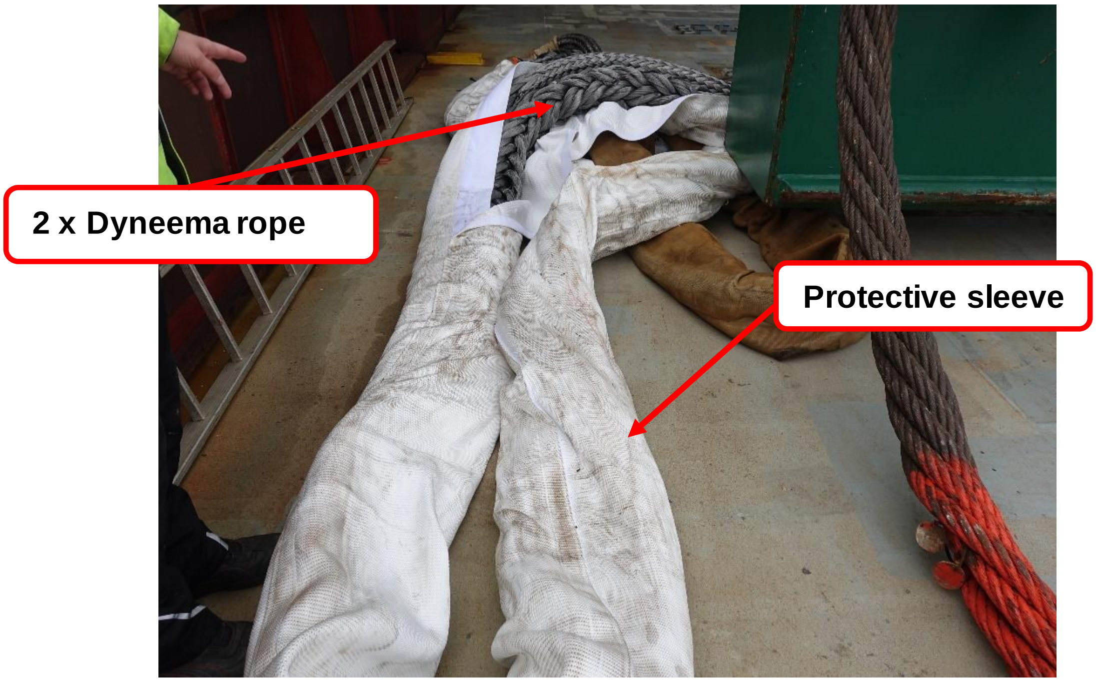

Figure 15: Lifting sling from the conical part of the MP

The complete arrangement of the lifting traverse and lifting slings is shown in Figure 9. One ring on the 27.5 m-long lifting sling made by GeoGleistein is hung directly into the traverse, while the other ring is attached to an extension bracket, which is also hung directly on the traverse, by means of a shackle. The spacing between the slings on the crane traverse for single-crane operation can vary between 11.8 m and 16.0 m. The 16.0 m spacing for this lift was required for structural reasons due to the bulge of the earthing brackets on the MP, as well as due to the bearing blocks on the SPMT and the deck.

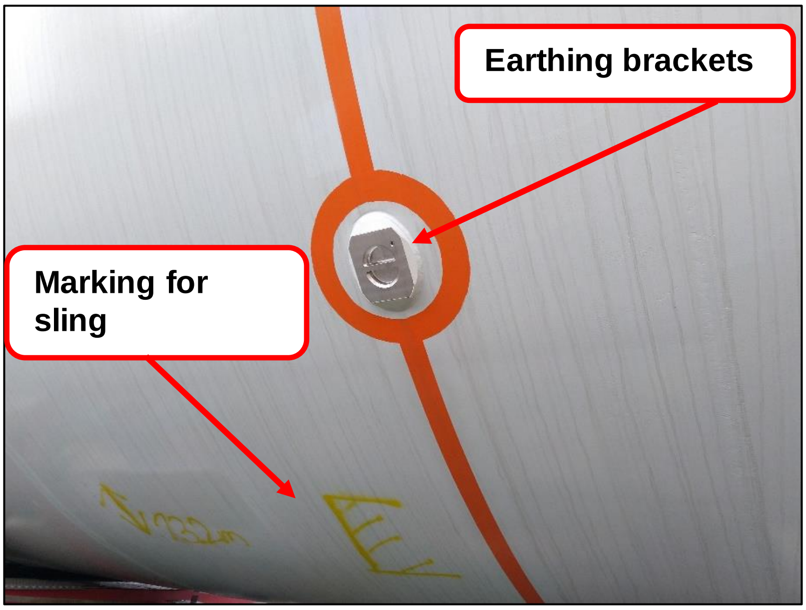

Figure 16: Position of lifting slings and earthing bracket (other lift)

The lifting sling consists of two 120 mm-thick Dyneema 12-plait braids, which lie parallel to each other and are held together by a protective sleeve fixed around them by Velcro fasteners.
The lifting sling attached to the conical part of the MP exhibited no tearing. However, fusion with the protective sleeve, which was no longer at its original position, and traces of wear were visible.

The lifting sling in the cylindrical part exhibited complete and partial tearing, as well as complete and partial fusing of strands. The protective sleeve was completely severed and exhibited other cuts and wear. The above damage can be explained by the sling slipping over the bulge of the earthing brackets on the MP.

The manufacturer tested and measured the lifting slings before delivery. The readings were within the range of tolerance. The length of the sling in the conical part was measured at 27.4 m. The length of the sling in the cylindrical part was 27.7 m.

A subjective examination of the older protective sleeves revealed that they had a rougher surface due to wear and the new protective sleeves used felt smoother than the old ones.

3.2.7 MP A28

The diameter of the MP that fell out of the crane was 8.1 m in the cylindrical part and 7.971 m at the point at which the sling and conical part were attached. According to the readings on the crane operator's display and on the bridge, the MP's total weight stood at 814 t.

3.2.8 Witness testimony

The lift plan states that the cylindrical end should be raised first. It was calculated that the inclination should not exceed roughly 1.76° in the worst case, with the cylindrical part being higher. The witnesses saw that the MP first lifted at the conical end and then at the cylindrical end. During the lift, a height difference of roughly 15-20 cm was observed. A difference of 20 cm corresponds to an inclination of about 0.2°. This slight inclination was not considered critical and since one witness confirmed that the MP was not tilted but in a horizontal position after being lifted from the SPMT, evidently not noticeable. This witness states that the speed was no different from what it would otherwise have been and that there was no jerkiness in the remainder of the operation. Another witness describes the speed of the lift/swing operation as swift.

According to witness testimony, the ship's general alarm was triggered directly in connection with the accident.

4 ANALYSIS

Witness testimony, photographs, video recordings, investigation reports from GeoGleistein, investigation report from Sal Heavy Lift, as well as expert opinions from the Institute of Mechanical Handling and Logistics at the University of Stuttgart and the Institute of Photogrammetry and Geoinformation at the Leibniz University of Hannover were available for the investigation and analysis of the accident.

4.1 Controlling the loading and unloading operation

The master controls the loading and unloading operation from the bridge. The control panel for the ballast pumps and the display for monitoring the loads on the crane hook are located on the port side looking aft. The maximum list is limited to 3° of inclination due to the aft ballast pontoon on the starboard side. The cranes and the bridge have an alarm for the event of a list exceeding 3°.
Taking into account the auxiliary crane (number 1) as a ballast counterbalance, the maximum list of no more than 0.5° should have been maintained for this lift. The bridge and every crane operator's cabin are equipped with list indicators. According to the interview, the ship listed within this specified range and no alarms were reported on the day of the accident.

4.2 Video recordings

The port operator's video recordings, which are triggered by motion detectors, were available for the investigation of the accident. The lift/swing operation cannot be seen in its entirety and continuously because this camera is only triggered when people or vehicles are in motion. No jerky or rapid rotational movements can be seen in the recordings or calculated from the running timeline of the recordings, however. The recordings were analysed with the involvement of representatives of the owner. The lift/swing operation was executed without any jerky movements, which is also confirmed by witnesses.

Figure 17: Still image of video recordings

4.3 Centre of gravity marking, sling position and weight

Based on Figures 10 and 11, which were taken on the day of the accident, the Institute of Photogrammetry and Geoinformation at the Leibniz University of Hannover analysed the centre of gravity and the sling positions. The MP's overall centre of gravity is marked by a circle with north-east/south-west quadrants painted black. According to the CAD drawing submitted by the owner, this centre of gravity should be 28.258 m (but according to the workshop drawing of the MP's manufacturer, 28.412 m) from the cylindrical end. The two slings should be positioned 8.0 m from and on each side of this centre of gravity.

The photogrammetric analysis (measuring accuracy: ± 12 mm) showed that the centre of gravity (based on the owner's drawing) marking was off-centre by 12.3 cm toward the conical part. This centre of gravity marking was confirmed by KMR-Marine Surveyors GmbH's geometrical measurement of MP A28.
The distance from the slings to this marked centre of gravity is 8.189 m toward the conical part and 7.741 m toward the cylindrical part. The analysis of the two photographs revealed that from the lift (Figure 10) to the crane being turned by 90° (Figure 11), there was no displacement of the slings.

The manufacturer of the MP sent the BSU workshop drawings which are not identical to the drawings of the owner. Additional parts were attached during the manufacturing process, which caused a shift in both the centre of gravity and total weight. According to these workshop drawings, the centre of gravity is 28.412 m from the cylindrical end. A publicly appointed surveyor checked this marking of the centre of gravity on the MP on behalf of the manufacturer and confirmed a deviation of 6.4 mm.

The manufacturer states that the total weight of the MP is approximately 775 t with the additional attachments. The drawing available to the owner is marked 'total weight 764 tonnes'. KMR-Survey calculated a total weight of 789.324 t after measuring the MP, while the displays on board indicated 814 t during the loading operation.
The MP's weight only plays a secondary role in this accident, as the safety margins were sufficient (SWL: 1,000 t) and the failure of the crane system, the lifting gear and the lifting slings did not cause the accident.

4.4 Static friction

Tests were carried out under laboratory conditions at the Institute of Mechanical Handling and Logistics to calculate the coefficients of friction and sliding angles on a cylindrical and conical test specimen. Friction plates with original coating applied by the Rostock-based coating company were produced for the series of tests. A DynaOne rope from GeoGleistein with a diameter of 12 mm and protective sleeve was used for the series of tests with the tensile testing machine. Tests were carried out with dry and wet sleeves, as well as with a sleeve from the slings damaged on board. At the beginning of the test the rope was pulled on the testing machine to a defined rope tension and a defined transverse force was applied.

Rope tension [kN]	Transverse force [kN]	Condition of sleeve	Mean coefficient of static friction
15	1	Dry	0.076
15	2	Dry	0.070
15	1	Wet	0.059
15	2	Wet	0.046
30	1	Dry	0.098
30	2	Dry	0.074
30	1	Wet	0.060
30	2	Wet	0.053
30	1	Dry and used	0.055
30	2	Dry and used	0.057

Figure 178: Series of tests to calculate the coefficient of static friction

The testing revealed that depending on the transverse force, the coefficient of static friction in the wet test setup reduces to 61-77% of the dry and new condition. With a dry and new protective sleeve and used part from on board, the coefficient of static friction reduces to 56-77% of the dry and new condition.

To evaluate the behaviour of the coefficient of friction when exposed to wear, tests were carried out on a bending machine at the Institute of Mechanical Handling and Logistics. The rope end was pulled through the device for 100 cycles and the coefficient of friction was determined in the process.

Rope tension [kN]	Transverse force [kN]	Condition of sleeve	Number of cycles	Mean coefficient of static friction	Reduction [%]
30	**2**	Dry	**0**	**0.078**	**16.7**
30	**2**	Dry	**100**	**0.065**	
30	**2**	Wet	**0**	**0.075**	**9.3**
30	**2**	Wet	**100**	**0.068**	

Figure 19: Calculation of coefficients of static friction when exposed to wear

After 100 cycles there were reductions of 16.7% and 9.3% when dry and wet, respectively.

The final test on the tensile testing machine was designed to calculate the sliding angle on a cylindrical and conical test specimen. Mean sliding angles of 7.5° when dry and 5.9° when wet were calculated for the cylindrical test specimen. Negative sliding angles of -3.4° when dry and -3.3° when wet were calculated for the conical test specimen. A negative sliding angle is in the direction of the thinner part of the cone.

Test specimen	Condition of sleeve	Mean sliding angle [°]
Cylinder	**Dry**	**7.5**
Cylinder	**Wet**	**5.9**
Cone	**Dry**	**-3.4**
Cone	**Wet**	**-3.3**

Figure 180: Calculation of the sliding angle

All the static friction tests under laboratory conditions have shown that moisture between the lifting sling and MP reduces static friction by 23-39% and the lifting slings start to slip more quickly than when dry. New lifting slings have higher static friction than those in use for longer. In the cylindrical part of the MP, the sling only slips when wet at an angle of inclination of about 5.9°. The MP's cone has an inclination of 5°. In the case of the calculated sliding angle of -3.3/-3.4°, this means that there is a considerable risk of slipping on the MP's cone surface, despite the vertical attachment of the lifting slings.

5 CONCLUSIONS

This accident caused substantial material damage but fortunately happened without anybody being seriously injured. The MP slipped out of the slings unpredictably due to a combination of several factors, where the extremely low friction between the MP and lifting slings must be regarded as material. Friction tests have shown that the friction actually present was significantly lower than would have been expected based on the specifications published. This low friction was reduced further by the presence of moisture.
The positioning of the slings was inaccurate vis-à-vis the marked centre of gravity but within an acceptable range considering the MP's extremely low inclination of 0.2° after lifting.
Another factor was that various drawings with altered centre of gravity were submitted to the BSU. Additional attachments, which were only visible on the workshop drawing, shifted the marked centre of gravity toward the conical part.

6 ACTIONS TAKEN

The owner held a workshop for the crew members involved in the lift and issued an internal safety directive to the other ships in its fleet after the accident. The following measures were introduced to make lifting with a crane safer:

1.) In contrast to previous lifting operations, a lifting sling may no longer be attached to the conical part of the MP in this project.

2.) A distance of at least 400 mm from the earthing brackets must be maintained.

3.) A crane deployment report must be prepared in accordance with a form for each lift of a MP in single-crane operation.

4.) The maximum inclination of a MP when being lifted in single-crane operation, where both lifting slings may only be placed on the cylindrical part, is 1°.

5.) The specified inclination is measured during a lift using a digital spirit level attached to the MP with magnets. The master can read the current value by means of remote indication on a mobile phone.

Figure 191: Inclinometer on a MP

7 SAFETY RECOMMENDATIONS

Since the measures taken by the owner increase safety to the extent that it is highly unlikely that an accident of this nature will be repeated, we have dispensed with issuing a safety recommendation.

It is not within the remit of the BSU to evaluate the shore-based processes for the transmission of drawings and data from the manufacturer to the owner but there does seem to be a need for improvement in this regard.

8 SOURCES

- Enquiries of the WSP
- Written statements
  - Ship's command
  - Owner
- Witness testimony
- Expert opinion/technical paper
- Navigational charts and ship particulars, Federal Maritime and Hydrographic Agency
- Official weather report by the DWD