MA2014-10

MARINE ACCIDENT
INVESTIGATION REPORT

October 30, 2014

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Norihiro Goto
Chairman,
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

MARINE ACCIDENT INVESTIGATION REPORT

Vessel type and name: Container ship PANCON SUCCESS
IMO number: 9635420
Gross tonnage: 9,892 tons

Accident type: Fatality of a crew member
Date and time: Around 20:25 on February 7, 2013
Location: In the area around Mariyama Minami Quay A in Tsuruga Port, Tsuruga City, Fukui Prefecture
On a true bearing of approximately 055° and at a distance of 600 m from the Kanegasaki Breakwater Lighthouse, Tsuruga Port (approximately 35°40.1'N, 136°03.9'E)

September 25, 2014
Adopted by the Japan Transport Safety Board

Chairman	Norihiro Goto
Member	Tetsuo Yokoyama
Member	Kuniaki Shoji
Member	Toshiyuki Ishikawa
Member	Mina Nemoto

SYNOPSIS

< Summary of the Accident >

At around 20:25 on February 7, 2013, while the container ship PANCON SUCCESS with the master, chief officer and 14 other crew members onboard and loaded with 128 containers (approximately 1,500 tons in weight) was moored at Mariyama Minami Quay A in Tsuruga Port, Tsuruga City, Fukui Prefecture, one of the ship's mooring lines was severed and subsequently struck the chief officer, who died from his injuries.

< Probable Causes >

It is probable that while the PANCON SUCCESS was moored at Mariyama Minami Quay A in Tsuruga Port at night, this accident occurred when one of the ship's mooring lines was severed and struck the chief officer.

It is probable that the mooring line was severed as a result of the longitudinal and lateral motions of the PANCON SUCCESS caused by secondary undulation present at that time in Tsuruga Port.

It is probable that the severed mooring line struck the chief officer because he was in the mooring winch operating area, which was within the snap-back danger zone.

It is somewhat likely that the PANCON SUCCESS remained moored at Mariyama Minami Quay A because the master had no knowledge of secondary undulation.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

At around 20:25 on February 7, 2013, while the container ship PANCON SUCCESS with the master, chief officer and 14 other crew members onboard and loaded with 128 containers (approximately 1,500 tons in weight) was moored at Mariyama Minami Quay A in Tsuruga Port, Tsuruga City, Fukui Prefecture, one of the ship's mooring lines was severed and subsequently struck the chief officer, who died from his injuries.

1.2 Outline of the Accident Investigation

1.2.1 Setup of the Investigation

On February 13, 2013, the Japan Transport Safety Board appointed an investigator-in-charge and another investigator to investigate this accident.

1.2.2 Collection of Evidence

February 14, March 6, and November 1, 2013: Interviews and receipt of written responses to questionnaires

February 18 and March 14, 2013: Interviews

February 19, 2013: On-site investigation, interviews and receipt of written responses to questionnaires

March 28, April 15 and April 17, 2013: Receipt of written responses to questionnaires

1.2.3 Investigational Cooperation Provided

Cooperation was provided by Professor Kazusei Yamamoto of the Marine Technical College, Marine Technical Education Agency (an independent administrative institution) in investigating matters related to the accident, including estimating the cause of severance of the mooring line.

1.2.4 Comments from Parties Relevant to the Cause of the Accident

Comments on the draft report were invited from parties relevant to the cause of the accident.

1.2.5 Comments from the Flag State

Comments on the draft report were invited from the flag state of the PANCON SUCCESS.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

2.1.1 Ship's Movements Based on the Records of the Automatic Identification System

According to the data of the Automatic Identification System (AIS)*1 received by a private vessel information company, the movements of the PANCON SUCCESS (hereinafter referred

*1 The Automatic Identification System (AIS) is a tracking system with which ships automatically transmit and receive vessel information such as identification code, type, name, position, course, speed, destination, navigational status and other safety-related information to exchange such information with other nearby ships and shore stations including navigational aid facilities.

to as “the Vessel”) from 15:56:00 to 21:04:49 on February 7, 2013 were as indicated in the following table.

Time (hh:mm:ss)	SOG (kn)	Position		COG (°)*	Heading (°)*
		Latitude (N) (° – ' – ")	Longitude (E) (°– ' – ")		
15 : 56 : 00	0.3	35-40-07.0	136-03-45.3	225.5	266.0
15 : 59 : 10	0.3	35-40-06.8	136-03-54.9	208.9	265.0
16 : 01 : 39	0.3	35-40-06.4	136-03-54.9	263.5	268.0
17 : 13 : 51	0.2	35-40-06.3	136-03-54.7	357.6	269.0
17 : 25 : 49	0.0	35-40-06.2	136-03-54.7	001.9	270.0
18 : 19 : 50	1.1	35-40-06.3	136-03-54.7	001.2	270.0
18 : 52 : 52	0.1	35-40-06.3	136-03-54.6	162.7	269.0
18 : 55 : 51	0.7	35-40-06.3	136-03-54.6	353.8	269.0
19 : 07 : 50	0.2	35-40-06.3	136-03-54.6	005.1	269.0
20 : 10 : 49	0.2	35-40-06.3	136-03-54.6	319.9	269.0
20 : 16 : 49	0.2	35-40-06.2	136-03-54.7	179.8	269.0
21 : 04 : 49	1.0	35-40-06.2	136-03-54.7	185.7	269.0

*: All COGs and headings are in true bearing (this also applies hereinafter in this report).

2.1.2 Process and Progress of Accident According to the Statements of Crew Members and Others

The events leading to this accident according to the statements of the master and the boatswain of the Vessel, the responsible person of the sole agency in Japan and the responsible person of the ‘ship’s agency at Tsuruga Port’ (hereinafter referred to as “the Agency”), and also according to the questionnaire responses from the sole agency in Japan were as follows:

(1) The Vessel

The Vessel left Fushiki Toyama Port, Toyama Prefecture, at around 18:00 on February 6, 2013 with the master, chief officer (hereinafter referred to as “the C/O”) and 14 other crew members onboard (11 persons holding the nationality of the Republic of Korea and 5 persons holding the nationality of the People’s Republic of China) and loaded with 128 containers (approximately 1,500 tons in weight) and set sail for Kanazawa Port, Ishikawa Prefecture.

The master had scheduled cargo handling operations at Kanazawa Port for around noon the next day. However, after learning that another ship occupied the berth for cargo handling and the Vessel would have to wait offshore in poor weather conditions, he decided to skip*2 Kanazawa Port and set sail for Tsuruga Port.

At around 16:10, the Vessel berthed port side alongside at Mariyama Minami Quay A (hereinafter referred to as “the Quay”) in Tsuruga Port and was moored with the bow draught at approximately 5.15 m and the stern draught at approximately 6.70 m.

At around 17:00, the master was informed by the responsible person of the Agency that cargo handling was suspended for that day and would resume the next morning if the weather improved.

At around 19:20, the ordinary seaman on gangway watch duty found that in the stern area, of

*2 The term “skip” means to cancel the scheduled port call.

the three stern lines,*3 the one closest to the stern (hereinafter referred to as "Mooring Line A") and, of the two spring lines,*4 the one closest to the bow (hereinafter referred to "the Mooring Line B") were severed. To deal with this, the C/O together with the boatswain and 3 other crew members started to replace Mooring Line A and Mooring Line B.

On the Vessel, to proceed with the replacement of Mooring Line B after the completion of replacement of Mooring Line A, an engineer went to the engine room, the C/O took his position at the mooring winch operating area to remove the remaining Mooring Line B on the hawser drum,*5 the boatswain and an ordinary seaman took their positions in the area between the fairlead*6 on the Vessel's side and the mooring winch, and the other ordinary seaman took his position in the vicinity of the bitt*7 on the Quay to which the spring line was secured.

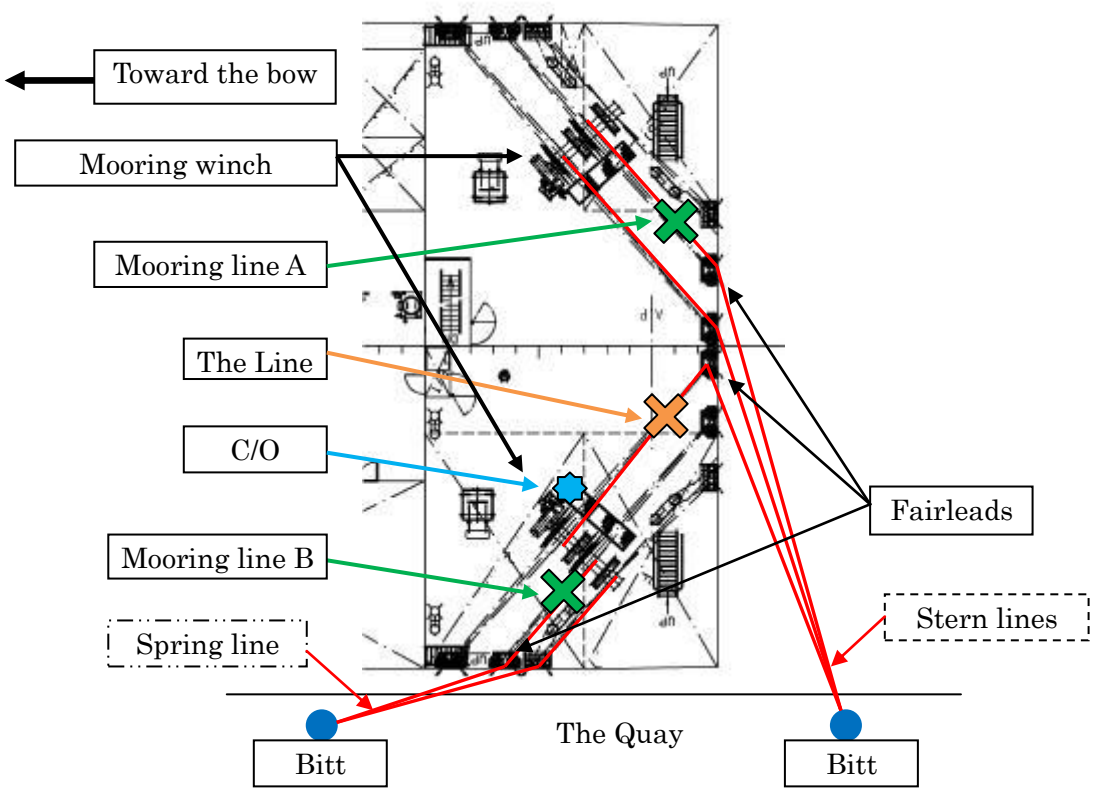
On the Vessel, while Mooring Line B was being replaced, the stern line (hereinafter referred to as "the Line") that led from the portside mooring winch to the bitt on the Quay through the fairlead at the central part of the Vessel's stern was severed at around 20:25 and the Line struck the C/O on his buttocks, knocking him down.

Finding that the C/O had fallen down, the boatswain informed the second officer inside the Vessel, and the second officer contacted the master who was then outside the Vessel.

The master contacted the responsible person of the Agency requesting a call for help and returned to the Vessel at around 21:00.

(Refer to Figure 2-1.)

*3 Stern lines are mooring lines that extend aft from the stern of a ship.
*4 Spring lines are mooring lines that extend aft from the bow or forward from the stern of a ship.
*5 The hawser drum is a device with a rotating drum around which a mooring line is wound. The line is played out or rewound by turning the drum.
*6 The fairlead is a fitting, such as a roller, used to guide a line toward the intended direction.
*7 The bitt is an iron post that is set on a quay or the like to secure the mooring lines.



X marked on the line indicates the severed point.

Figure 2-1 Stern Section of the Vessel

(2) The Agency

On the morning of February 7, the responsible person of the Agency received a request from the Vessel to change the port rotation between Tsuruga Port and Kanazawa Port due to skipping Kanazawa Port and calling at Tsuruga Port.

The responsible person of the Agency replied to the Vessel with a request for the consent of the Vessel's owner or other responsible party due to the inappropriateness of the Agency alone deciding on the changing in port rotation. A response was received from the Vessel advising that consent had been given.

Although cargo handling for the Vessel was to start normally since it had called at the port at around 15:40, due to the fact that the Vessel was swaying and there was a strong westerly wind exceeding the 16 m/s cargo handling suspension criteria of the Agency, the responsible person of the Agency told the master, at around 17:00, that the cargo handling would not be carried out that day.

At that time, the responsible person of the Agency advised the master to take refuge in an anchorage area indicating that the Quay was susceptible to the effect of the waves, that there was a risk of damage to the hull if the Vessel started swaying, and that worsening weather conditions were expected because of an approaching low pressure system. However, the person realized that the master intended to keep the Vessel moored at the Quay.

After being informed of the occurrence of injury by the master at around 20:31, the responsible person of the Agency arrived at the Quay at around 21:00. As the Vessel was repeatedly moving close to and away from the Quay, he managed to jump onto the gangway ladder, which was also moving together with the swaying Vessel. He checked the condition of the C/O and called an

ambulance.

The rescue crew of the local fire authority arrived at the Quay at around 21:24 and started rescue operations, but it was impossible to carry out the C/O using the gangway ladder. The master asked the responsible person of the Agency to request a tug boat; the tug boat thus dispatched pushed the Vessel at its stern and the C/O was carried out from the Vessel using the deck crane at the stern.

The C/O was taken to hospital, where he was confirmed dead.

The accident occurred at around 20:25 on February 7, 2013 in a location around the point at 055° and 600 m from the Tsuruga Port Kanegasaki Breakwater Lighthouse.
(See Figure 1 "Location and Time of Occurrence of the Accident" and Figure 2 "General Arrangement of the Vessel".)

2.2 Fatality of Persons

According to the questionnaire responses from the sole agency in Japan, the C/O was confirmed dead at the hospital to which he was transferred, and the cause of death was certified as hemorrhagic shock due to multiple open pelvic fractures.

2.3 Damage to Vessel

According to the statements of the master and boatswain, there was no damage to the Vessel, but five mooring lines at the stern were severed.

2.4 Crew Information

(1) Gender, Age, and Certificate of Competence

Master – Male, 58, nationality: the Republic of Korea
First Class Deck Officer Certificate (issued by the Republic of Korea)
Date of issue: December 18, 2012 (Valid until January 7, 2018)

C/O – Male, 54, nationality: the Republic of Korea
First Class Deck Officer Certificate (issued by the Republic of Korea)
Date of issue: May 29, 2012 (Valid until December 31, 2016)

Responsible person of the Agency – Male, 38

(2) Main Seagoing Experience and Other Related Information

1) Master

The following information is based on the master's statements.

a. Main Seagoing Experience

The master had about 33 years of seagoing experience, including 14 years in the position of master. He had served as the master of the Vessel since it was delivered in November 2012. His experience in calling at Tsuruga Port started with his employment on the Vessel, and this accident occurred on his eighth call at the port.

b. Physical Condition

He was in good health.

2) C/O

The following information on the C/O is based on the master's statements and the questionnaire responses from the sole agency in Japan.

a. Main Seagoing Experience

The C/O had about 32 years of seagoing experience and had served as chief officer of the Vessel since January 7, 2013.

b. Physical Condition

No health problems or other negative conditions were reported.

3) Responsible Person of the Agency

According to the statements of the responsible person of the Agency, he had been engaged in handling containers and other international cargo for about 12 years.

2.5 Vessel Information

2.5.1 Particulars of Vessel

IMO number: 9635420
Port of registry: Jeju, the Republic of Korea
Owner: Pan Continental Shipping Co., Ltd. (hereinafter referred to as "Company A")
Management company: Company A
Gross tonnage: 9,892 tons
L×B×D: 140.11 × 22.70 × 11.20 m
Hull material: Steel
Engine: Diesel engine × 1
Output: 8,280 kW
Propulsion: Fixed-pitch propeller × 1
Classification society: Korean Register of Shipping (hereinafter referred to as "Classification Society A")
Date of delivery: November 2012

2.5.2 Other Relevant Vessel Information

(1) Construction of Stern

According to the questionnaire responses by the sole agency in Japan, the Vessel is a container ship of an aft bridge type having mooring equipment located in the stern section of the upper deck, and above which Deck A is provided for loading containers.

(See Photo 2-1 and Figure 2-2.)

Photo 2-1 The Vessel

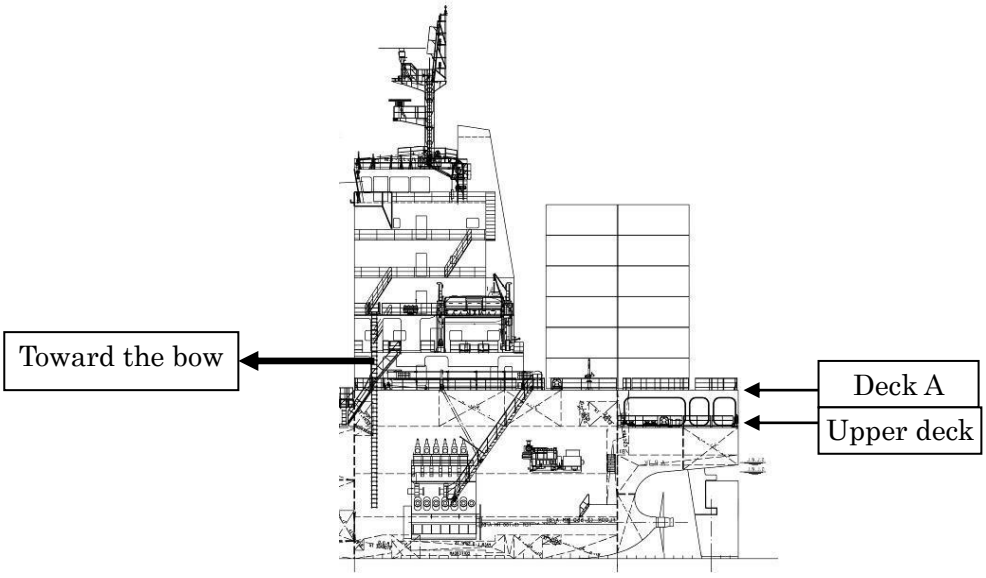


Figure 2-2 Arrangement of Stern

(2) Mooring Equipment at Stern Section

According to the statements of the master and the boatswain and also the questionnaire responses from the sole agency in Japan and Classification Society A, the mooring equipment at the stern section of the Vessel was in the following condition:

The mooring equipment at the stern section of the Vessel consists of two electrohydraulic mooring winches located one on each side; each winch has two hawser drums and warping ends.*8

Both hawser drums can be driven independently through control using a dog clutch, and the braking force of each drum measures 32.8 tf.

At the time of the accident, the C/O was operating the mooring winch on the port side; he disengaged the clutch of the winch's starboard side hawser drum while applying its brake and engaged the clutch of the portside hawser drum while releasing its brake.

(See Figure 2-3 and Photo 2-2.)

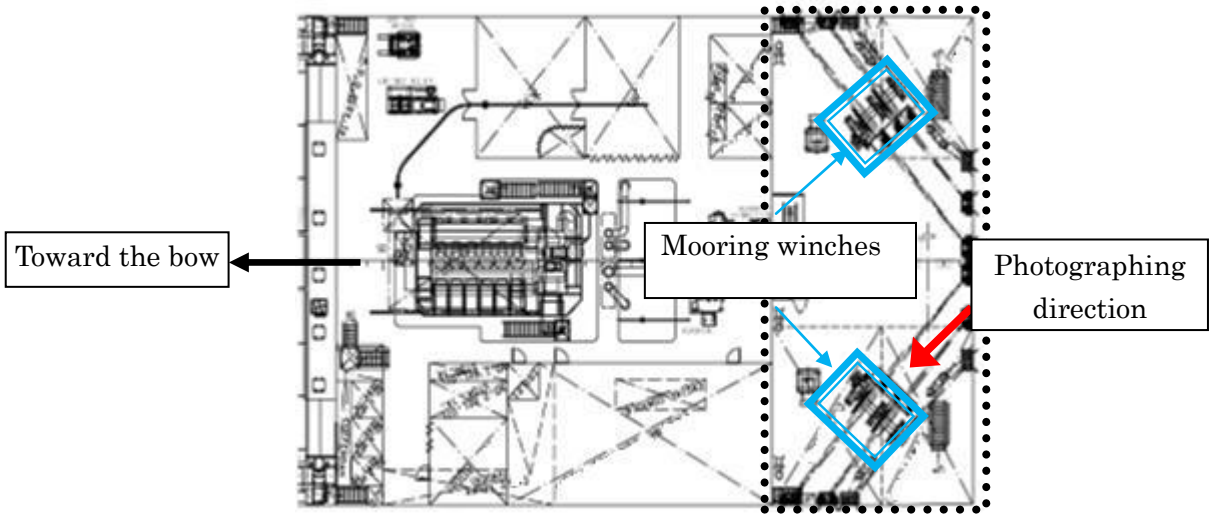


Figure 2-3 Arrangement of Mooring Winches

*8 The "warping end" is a warping drum of the mooring winch, on which a rope or the like is wound by utilizing the frictional effect.

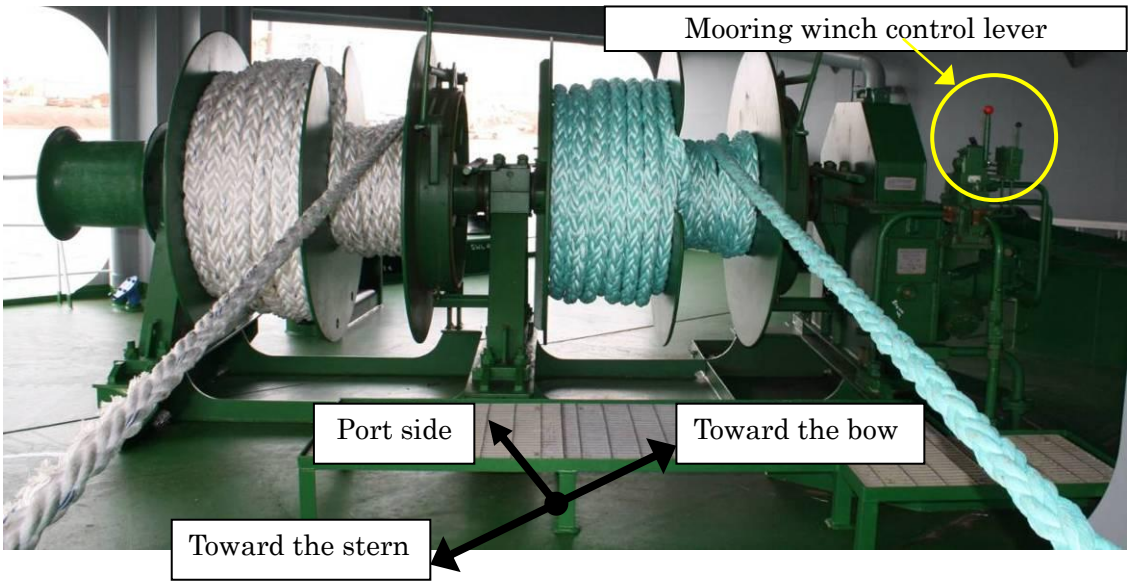


Photo 2-2 Port Side Mooring Winch

(At the time of the accident, the mooring line on the stern side ran through the portside fairlead and the mooring line from the portside fairlead was wound on the warping end.)

(3) Mooring Lines

According to the statements of the master and the boatswain and also the questionnaire responses from the sole agency in Japan and Classification Society A, the mooring lines of the Vessel were in the following condition:

The breaking load and length requirements stipulated by Classification Society A for the mooring lines with which the Vessel was to be equipped were, respectively, 38.5 tf or higher and 190 m or longer.

The mooring lines used for the Vessel at the time of the accident were polypropylene lines of 65 mm in diameter, 41 tf in breaking load and 190 m in length. At Tsuruga Port, the Vessel was moored with five lines at the bow and five lines at the stern although it was usually moored with four lines at the bow and four lines at the stern in other Japanese ports.

The Line was found to have severed at a point approximately 4 m away from the hawser drum and the cut ends of the yarn*9 were on almost the same plane showing melt marks.

(See Photo 2-3 and Photo 2-4.)

*9 "Yarn" is composed of strands of intertwining fibers.

Photo 2-3 Severed End of the Line

Photo 2-4 Melt Marks on the Severed End of the Line

(4) Other Relevant Information

According to the statements of the master and the boatswain, the Vessel had no problems or failures with the hull, engine or any equipment, and was swaying close to and away from the Quay (approximately 70 to 90 cm) at the time of the accident.

2.6 Information on Safety Management Manual

According to the questionnaire responses from the sole agency in Japan, the safety management manual of Company A did not include any stipulations concerning the procedure to follow in the case of a severed mooring line.

2.7 Weather and Sea Conditions

2.7.1 Weather

The weather data recorded by the Tsuruga Special Regional Weather Observation Station located about 2 km south of the site of the accident at the time of its occurrence, was as follows:

17:00 Temperature: 5.7°C, Average wind velocity: 7.6 m/s, Wind direction: west-northwest, Peak gust: 14.8 m/s, Wind direction: west-northwest

19:00 Temperature: 3.6°C, Average wind velocity: 7.2 m/s, Wind direction: west-northwest, Peak gust: 13.6 m/s, Wind direction: northwest

20:00 Temperature: 3.1°C, Average wind velocity: 8.3 m/s, Wind direction: northwest, Peak gust: 12.7 m/s, Wind direction: northwest

20:20 Temperature: 3.0°C, Average wind velocity: 7.1 m/s, Wind direction: west-northwest, Peak gust: 13.8 m/s, Wind direction: west-northwest

20:30 Temperature: 2.8°C, Average wind velocity: 7.4 m/s, Wind direction: west-northwest, Peak gust: 13.4 m/s, Wind direction: west-northwest

21:00 Temperature: 2.4°C, Average wind velocity: 7.8 m/s, Wind direction: northwest, Peak gust: 12.2 m/s, Wind direction: northwest

2.7.2 Weather Observations by the Crew

According to the statements of the master regarding the weather and sea conditions: At

around 17:00, it was snowing with a westerly wind at a velocity of 5 to 7 m/s and there were no wind waves despite the presence of surge, which made him feel that the weather was unlikely to worsen. The weather at around 20:00 was not so different from that at around 17:00, but the blowing wind was northwesterly and its velocity was about 10–12 m/s with the peak gust at about 15 m/s.

According to the statements of the responsible person of the Agency, the wind at around 17:00 was westerly and its velocity exceeded 16 m/s, the company's criterion value for suspending cargo handling operations.

2.7.3 Secondary Undulation

(1) According to the statements and questionnaire responses by the responsible officer of the Japan Meteorological Agency, there was a low pressure system moving east over the Japan Sea on the day of the accident, and it was possible that the pressure vibration phenomenon developed under the influence of the low pressure system. Secondary undulation in Tsuruga Port persisted throughout the day of the accident. (See Figure 2-4.)

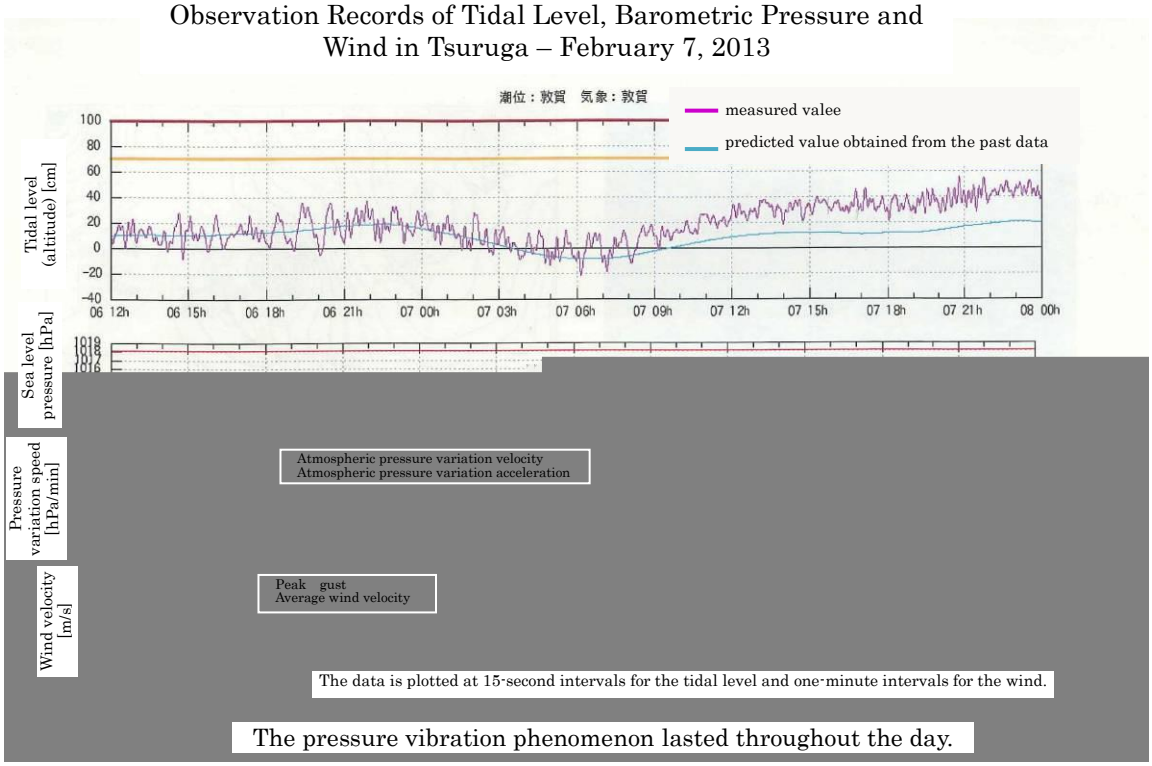


Figure 2-4 Observation Records of Tidal Level, Barometric Pressure and Wind in Tsuruga

(2) The secondary undulation was described as follows according to the information posted on the website of the Japan Meteorological Agency in addition to the statements and questionnaire responses by the responsible officer of the agency:

When the cycle of high and low tides repeated about twice a day under the effects of celestial movement are regarded as the main tidal undulation, the phenomenon of the rising and lowering sea level at intervals between several minutes and several tens of minute initiated by other causes is called the secondary undulation.

The secondary undulation occurring in such areas as bays and narrows varies depending on their shape (including depth and size) and it is generally initiated by fluctuation of the sea level

due to meteorological disturbances such as typhoons and low pressure systems when the natural frequency prevailing in a bay or the like is appropriate for triggering resonances. Secondary undulation is not rare and the phenomenon occurs on any Japanese coast. However, if the period of undulation is close to the natural frequency of the water in a bay or the like, the resulting resonance may cause extremely large changes in sea level.

In addition, the shape of certain bays or narrows causes the repeated reflection of waves and the secondary undulation may persist for several days as a result. Secondary undulation can occur unexpectedly, even when the weather is fine with no nearby typhoon or developing low pressure system, which makes this phenomenon difficult to predict.

The Japan Meteorological Agency is constantly monitoring the tidal level and releasing the necessary information whenever required by the conditions. All people concerned must be on alert when a "tidal level warning related to secondary undulation" is given.

Secondary undulations occurring in the Tsuruga area are most often caused by meteorological disturbances generated in a nearby area.

(3) Literature*[10] on secondary undulation and long-period waves contains the following explanations:

3.3 Secondary Undulation

(1) Definition

The water in a circumferentially closed lake or in a bay having only a narrow passage that allows extremely limited water movements between it and the open sea self-oscillates at fixed periods depending on the change in wind and other physical effects. This phenomenon is called the seiche (standing wave). On the other hand, the oscillation of the water in a bay or port with a broad passage to the open sea allowing free incoming and outgoing of water is called the secondary undulation. The main point to be considered at the time of inspection of the port facility's performance is the secondary undulation with respect to the period and amplitude of oscillation.

There are two types of secondary undulation when broadly classified. The first one occurs in a bay and is triggered by a drop in barometric pressure or the wind-blown water under the effect of a typhoon. (Skipped)

The second one is an oscillation that is forced to develop inside a bay or port by high surf and long-period changes in water level and water flow that develop under the effect of the high surf. This oscillation sometimes causes an extensive resonance to the oscillation period unique to the shape of a certain bay or port. Especially artificially excavated ports having a rectangular shape and inside water surrounded by quay walls or other highly reflective facilities are vulnerable to secondary undulation.

The period of secondary undulation ranges roughly from several minutes to several tens of minutes and the amplitude may reach several tens of centimeters. The amplitude of secondary undulation experienced in Nagasaki Bay in the past measured as high as approximately 2 m. Secondary undulation, even when its amplitude is in the order of several tens of centimeters, often significantly obstructs the mooring of ships and cargo handling since it is accompanied by high-speed horizontal water flow. (Skipped)

*[10] Technical Criteria and Their Exposition for Port and Harbor Facilities July 2007, editorial supervision by the Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism, issued by the Ports & Harbours Association of Japan

(2) – (4) (Skipped)

4.4 Long-period waves

(1) Determining the measures against long-period waves and secondary undulation occurring in an individual port is required through observations conducted at that port as far as possible. In this literature, the long-period waves are defined as waves that consist of component waves having a period between 30 and 300 seconds, which are found included in the frequency spectrum obtained through analysis of the record of 20-minute or longer continuous observation.

(2) There are times of detecting a long-period change in water level of 30 seconds to several minutes at observation stations inside a port and at the offshore sea outside it, and the waves involving such water level changes are generally called long-period waves. If the natural oscillation frequency of the oscillation system formed by a ship and the mooring lines is close to the frequency of the long-period waves, a large surge will occur due to the effect of resonance even when the wave height is low, and such surge will adversely affect the rate of operation of the port. If long-period waves having a significant wave height of about 10 to 15 cm frequently occur in a port, it is recommended to consider appropriate countermeasures in both hardware and software aspects.

When a significant change of water level with a period of longer than several minutes is detected at an observation point inside a port, it is more likely to be caused by secondary undulations than by long-period waves. Secondary undulation is a result of minute disturbances generated by air pressure changes in the ocean and then amplified by the natural oscillation of a port, harbor or bay. The secondary undulation, if its amplitude grows remarkably large, may cause flooding at the back of a bay and backflow in drainage ditching in addition to locally high-speed currents that may cause small boats' mooring lines to sever. When designing a port or harbor, it is desirable to consider making its shape least vulnerable to the effect of secondary undulation. A small port or harbor such as a marina has a natural period close to that of the long-period waves, and this often causes a situation where the propagation of long-period waves from the ocean excites the secondary undulation. In this case, both phenomena are closely related to each other. When the excitation of secondary undulation by long-period waves becomes evident from the results of observation and calculation, it is desirable to consider both phenomena.

(3) – (10) (Skipped)

(4) Literature*[11] on the effects of long-period waves and control of the resulting damage contains the following description:

5. Effects of long-period waves in ports and measures against resulting damage

Long-period waves entering a port or the seiches induced by them have very long periods and thus involve large horizontal movement of water particles. This causes violent swaying motions in moored ships. The resulting problems with cargo handling are experienced daily and there are many reports on severed ropes as well as structural damage to the ship and hull due to collision against a quay, dock, pier or breakwater. Water flows swiftly under high pressure at a port entrance where the position matches the node of the seiche, eliminating the ships' freedom of movement and possibly even causing an accident. The Naval Operating Base at the Port of Los Angeles frequently suffers damage when sea waves having a three-minute

*[11] Sanae Unoki, Seiches in Ports and Harbors, Proceedings of the Sixth Coastal Engineering Lecture Presentation of Japan Society of Civil Engineers (1959), pp.9

period exceed a height of merely 0.2 ft. As seen from Table 3, which shows the damage incurred, the Base suffered a considerable number of accidents in just a few months. There were multiple cases of ships having bottomed the seabed at the time of low water and foundering when the tide came in again as they failed to get afloat. There were reported cases of especially large-scale seiche in which the land was covered by floodwater. These examples indicate that long-period waves including seiche are non-negligible challenges for those engaged in port and harbor engineering and operation, and these types of waves have been identified as surge, scend, undulation, run, groundswell, ressac and range. Mitchell was the first well-known port and harbor engineer who noted the importance of considering the effects of long-period waves. His followers then continued with observations and experiments to find measures for controlling the damage caused by these types of waves.

(Skipped)

(Table 3 – omitted)

(5) Literature*[12] on damage caused by long-period waves contains the following description:

2.1 Damage caused by long-period waves

(Skipped)

(1) Tomakomai Port

The Higashi-ko Area in Tomakomai has been partially in service since 1980. Figure 1 shows a plan view of the Higashi-ko Area in Tomakomai. At the stage of port planning, the shape of Tomakomai Port was designed to ensure that the significant wave height $H_{1/3}$ at the front of the quay remained lower than 50 cm for more than 98% of the total time within a year. However, since the East –14 m quay was placed in service in the port, there were reports of long-period swings occurring in moored boats and ships even when conditions in the port were relatively calm. It is known that the amplitude of the swing exceeded as much as 10 m in the surge direction depending on the case.

(Skipped)

Figure 3 shows the change in both significant wave height and period measurements taken at an observation point around the time of occurrence of swings in a moored ship; the shaded area corresponds to the period of time of large swings occurring in the ship. The swing amplitude increased to a maximum of 8 m in the shaded period of time, and due to the risk of severance of mooring lines, the ship was left the berth as an emergency. The characteristic observations taken within this period of time are that the wave height in the sea outside the port increased to a maximum of about 3 m and the significant wave period became longer than ten seconds around the time of occurrence of the swings in the ship. The significant wave height then measured at St. 1 in the port was smaller than about 0.5 m within the shaded area; this value is smaller than the limit wave height for cargo handling established as one of the technical criteria (by the Ports & Harbours Association of Japan in 1989) and thus represents a 'calm' condition.

In the observation in 1994, only a video recording was carried out from the quay, so the change in the significant and maximum values for both the amplitude of the surge (ship's longitudinal movements alongside the quay) and of the heave (ship's up and down movements) are shown. The shaded period of time in Figure 3 corresponds to the time from 00:00 to 08:30 on September 18, 1994 in Figure 4. Within this period of time, the

*[12] Tetsuya Hiraishi et al, Characteristics of Long-Period Waves Observed in Ports, Port and Airport Research Institute Report, Volume 35, Issue 3 (September 1996), pp.7-9

measurement of heave reached about 0.8 m at maximum and the maximum surge measurement increased to about 8.0 m. It was at this time that mooring of the ship was discontinued and the ship left the berth as an emergency because of the risk of broken mooring lines. The wave height still showed a tendency to increase after 08:30 on September 18, so the lines might have broken if the ship had continued to be moored.

(Skipped)

(Figure 1, Figure 3 and Figure 4 omitted)

(6) Ports with information on secondary undulation in the Sailing Directions*[13] issued by the Japan Coast Guard are as follows:

- Muroran Port (Muroran City, Hokkaido)
- Hakodate Port (Hakodate City, Hokkaido)
- Ominato Port (Mutsu City, Aomori Prefecture)
- Tsuruga Port (Tsuruga City, Fukui Prefecture)
- Maizuru Port (Maizuru City, Kyoto Prefecture)
- Sakaiminato Port (Sakaiminato City, Tottori Prefecture and Matsue City, Shimane Prefecture)
- Saigo Port (Okinoshima Town, Shimane Prefecture)
- Hamada Port (Hamada City, Shimane Prefecture)
- Futami Port (Ogasawara Village, Tokyo)
- Shimoda Port (Shimoda City, Shizuoka Prefecture)
- Suzaki Port (Suzaki City, Kochi Prefecture)
- Nagasaki Port (Nagasaki City, Nagasaki Prefecture)

2.8 Severance of the Line

Concerning the alteration in state and other effects that took place in the Line around the time of its severance, the following views were obtained from the professor of the Marine Technical College, Marine Technical Education Agency (an independent administrative institution).

2.8.1 State of the Line at the Time of Severance

Based on the fact that the yarn of the severed end of the Line was on almost the same plane and found to be melted, it is estimated that the Line had severed at the fairlead, a curved part at its base or some edge in the hull when it was tensioned.

The Line is reported to have severed on the deck, but according to the findings from past studies and the like, a line mooring a ship is stretched under tension and if it is severed at a fairlead or something at the stern, one end resiles toward the mooring drum and the other end toward the mooring point on the quay as does a stretched rubber band; so the mooring line's severed end on the mooring drum side is estimated to have reached the aft side of the drum and then returned to the drum's fore side, and so was found remaining on the deck.

The Line was probably tensioned with a force greater than its strength due to the swaying of the moored Vessel and the Line was also subject to compression force caused by the swaying of the Vessel in the section bent by the fairlead. Then, the Line probably underwent an instantaneous force exceeding its tensile and shear strength, finally resulting in severance.

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*[13] Pub. 101 S. & E. Coasts of Honshu Pilot March 2011
Pub. 102 N. W. Coast of Honshu Pilot March 2012
Pub. 103 Seto Naikai Pilot March 2013
Pub. 104 Coast of Hokkaido Pilot February 2008
Pub. 105 Coast of Kyushu Pilot February 2010

Past studies have shown that the breaking load of a line at a curved section is reduced to 90% of its breaking load determined by tensile test.

(See Figure 2-5.)

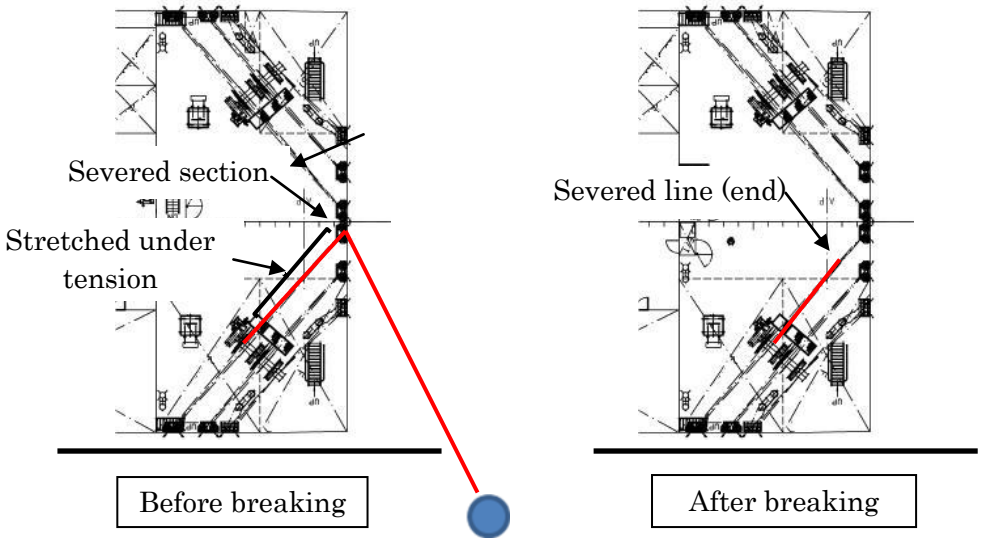


Figure 2-5 State Before and After Severance of the Line

2.8.2 State of the Line after Severance

When severed, a synthetic fiber line under tension produces a phenomenon called “snap back” in which the static energy accumulated in the line is released instantaneously. When snap back occurs, the instantaneous release of the accumulated energy causes the severed end of the line to spring back and strike an object in its way with a huge force.

Assuming that the Line was severed at the fairlead, the snap-back danger zone would extend over the range on the opposite side of the mooring drum that the severed end reaches from the mooring point on the mooring drum side as the center; the Line probably struck the C/O when it sprang back after the severance.

2.9 Characteristics of Tsuruga Port

(1) According to the statements of the responsible person of the Agency, the characteristic aspects of Tsuruga Port are as follows:

Cargo handling operations had been suspended about 10 times a year since the start of cargo handling operations on the Quay in October 2010. On the quay used until October 2010 at the south of the Quay, suspension had occurred at most only once a year. The responsible person of the Agency had experienced multiple cases of mooring line severance during cargo handling, although they are not included in the abovementioned count of 10 times. At the Quay, he often saw fishing boats in nearby areas swaying even when there were no visually noticeable waves, so it was difficult to visually determine whether or not there were undulations.

(2) According to the questionnaire responses from the Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport and Tourism, there were the following comments on the necessity of a breakwater plan in the reference material of the Tsuruga Port Plan (November 2005) submitted by the port management body of Tsuruga Port:

2) Necessity of a breakwater plan

Given that cargo handling operation is occasionally disrupted by such causes as surges

occurring in winter in front of the quays in the Mariyama Kita Area and Mariyama Minami Area, the breakwater plan in the North Mariyama Area needs to be expanded in order to ensure the necessary level of calmness.

(3) The Sailing Directions issued by the Japan Coast Guard contain the following information:

The secondary undulation in Tsuruga Port involves the repeated rising and lowering of the water level at periods of 10 minutes, 57 minutes, 65 minutes and so on and the rising and lowering of the water level may become as large as 0.2 m.

3 ANALYSIS

3.1 Situation of the Accident Occurrence

3.1.1 Course of Events

Based on the descriptions in paragraphs 2.1 and 2.5.2 (3), it is probable that the course of events leading up to the occurrence of the accident was as follows:

(1) At around 16:10 on February 7, 2013, the Vessel berthed port side alongside at the Quay in Tsuruga Port and was moored using five mooring lines each for the bow and the stern rather than four mooring lines each for the bow and the stern as was usually the case in other ports.

(2) At around 17:00, the Vessel was contacted by the responsible person of the Agency saying that cargo handling would be suspended due to prevailing winds that exceeded the criterion for suspending cargo handling operations.

(3) At around 19:20, the ordinary seaman on gangway watch duty on the Vessel found two severed mooring lines for the stern. Then, while the C/O and four other crew members were working to replace the severed mooring lines, the Line was severed.

(4) The C/O was struck by the severed Line and fell down. He was taken to hospital, where he was confirmed dead.

3.1.2 Date, Time and Location of the Accident

Based on the descriptions in paragraph 2.1, it is probable that the date and time of occurrence of the accident was February 7, 2013 at around 20:25, and the accident occurred in a location around the point at 055° and 600 m from the Tsuruga Port Kanegasaki Breakwater Lighthouse.

3.1.3 Damage to the Vessel

Based on the descriptions in paragraph 2.3, it is probable that there was no damage to the Vessel, but five mooring lines were severed.

3.1.4 Victims

As described in paragraph 2.2, the C/O died due to hemorrhagic shock caused by multiple open pelvic fractures.

3.2 Causal Factors of the Accident

3.2.1 Crew Members

Based on the descriptions in paragraph 2.4, the relevant particulars of the crew members concerned are as follows:

The master and the C/O held a legitimate and valid certificate of competence.

It is probable that the master and the C/O had no health problems.

It is probable that the master had experienced eight calls at Tsuruga Port.

3.2.2 Weather and Sea Conditions

Based on the descriptions in paragraph 2.7, it is probable that the weather and sea conditions were as follows:

(1) At the time of the accident, the weather was snowy, the direction of the wind was west-northwest to northwest, the wind velocity was about 7 to 8 m/s, and the peak gust was about 12 to 14 m/s.

(2) On the day of the accident, Tsuruga Port had a secondary undulation of a period between about 7 and 23 minutes and a total amplitude of about 2 to 17 cm, which lasted from 16:00 to 21:00; especially between 20:00 and 21:00, the period measured about 11 to 16 minutes and the total amplitude about 12 to 15 cm.

3.2.3 Motions of the Vessel

Based on the descriptions in paragraphs 2.1, 2.5.2, 2.7 and 2.9, it is probable that the secondary undulation caused the Vessel to repeat lateral motions (sway) in a range of about 70 to 90 cm while making longitudinal motions (surge).

3.2.4 Factors Leading to the Vessel Remaining Moored at the Quay

Based on the descriptions in paragraph 2.1, the factors concerned were as follows:

(1) It is probable that the master thought that the Vessel could remain moored at the Quay despite the advice given by the responsible person of the Agency at around 17:00 recommending taking refuge in an anchorage area because of expected worsening weather.

(2) It is somewhat likely that the master thought that the Vessel could remain moored at the Quay due to his lack of knowledge about secondary undulation.

3.2.5 Severance of Mooring Lines and Injury to C/O

Based on the descriptions in paragraphs 2.8, 3.1.1 and 3.2.4, it is probable that the Line was severed at its section bent by the fairlead when it was tensioned by the Vessel's longitudinal and lateral motions resulting from the secondary undulation and then the Line snapped back, striking the C/O, who was in the mooring winch operating area located within the snap-back danger zone.

3.2.6 Causal Factors of the Accident

Based on the descriptions in paragraphs 3.1.1 and 3.2.3 to 3.2.5, the events involved in the occurrence of the accident are as follows:

(1) It is probable that at around 16:10 on February 7, 2013, the Vessel berthed port side alongside at the Quay in Tsuruga Port and was moored using five mooring lines each for the bow and the stern.

(2) It is probable that at around 17:00, the Vessel was contacted by the responsible person of the Agency saying that cargo handling would be suspended due to prevailing winds that exceeded the cargo handling suspension criterion.

(3) It is somewhat likely that the master thought, due to his lack of knowledge about secondary

undulation, that the Vessel could remain moored at the Quay despite the advice given by the responsible person of the Agency at around 17:00 recommending taking refuge in an anchorage area because of expected worsening weather.

(4) It is probable that on the day of the accident, the Vessel was subjected to the effects of secondary undulation having a period between about 7 and 23 minutes and a total amplitude of about 2 to 17 cm from 16:00 to 21:00, and especially between 20:00 and 21:00, a period between about 11 and 16 minutes and a total amplitude of about 12 to 15 cm, so that the Vessel was surging and swaying.

(5) It is probable that at around 19:20, the ordinary seaman on gangway watch duty on the Vessel found two severed mooring lines and the C/O and four other crew members started replacing the severed mooring lines.

(6) It is probable that at around 20:25, on the Vessel surging and swaying due to secondary undulation, the Line under tension was severed at its section bent by the fairlead causing it to snap back, which made the severed line strike the C/O, who was in the mooring winch operating area located within the snap-back danger zone.

(7) The C/O was taken to hospital, where he was confirmed dead.

4 PROBABLE CAUSES

It is probable that while the Vessel was moored at the Quay in Tsuruga Port at night, this accident occurred when the Line was severed and struck the C/O.

It is probable that the Line was severed as a result of the longitudinal and lateral motions of the Vessel caused by secondary undulation present at that time in Tsuruga Port.

It is probable that the severed mooring line struck the C/O because he was in the mooring winch operating area, which was within the snap-back danger zone.

It is somewhat likely that the Vessel remained moored at the Quay because the master had no knowledge of secondary undulation.

5 SAFETY ACTIONS

It is probable that while the Vessel was moored at the Quay in Tsuruga Port at night, this accident occurred when the Line was severed and struck the C/O.

It is probable that the Line was severed as a result of the longitudinal and lateral motions of the Vessel caused by secondary undulation present at that time in Tsuruga Port.

It is probable that the severed mooring line struck the C/O because he was in the mooring winch operating area, which was within the snap-back danger zone.

It is somewhat likely that the Vessel remained moored at the Quay because the master had no knowledge of secondary undulation.

To utilize the above findings to improve safety, ship operators should: seek information on secondary undulation that poses a threat to ships for all ports at which the ships under their management call and distribute the information to the crew of each ship before it calls at the port; ensure that the crew members learn through educational instruction that secondary undulation causes lateral and longitudinal motions in ships and this in turn can cause damage to the hull or

severance of mooring lines; and instruct them to make the ship leave the berth without hesitation upon the occurrence of motions attributable to secondary undulation.

Ship operators should also give guidance to all crew members of the ships under their management to avoid, as far as possible, working near any mooring line at risk of severance given the possibility of death or injury if the line is severed and its end strikes a person.

5.1 Safety Actions Taken by Company A

After the occurrence of this accident, Company A informed all the ships under its management of the following findings and measures to be taken to prevent recurrence of a similar accident.

Probable causes of the accident

1) Re-securing of mooring lines was forcibly attempted under worsening weather conditions.
2) The Vessel should have grasped the meteorological conditions and when the conditions were such that it was difficult to secure the safety of the Vessel, necessary actions should have been taken such as leaving the berth and anchoring. There was a delay in making such decision.

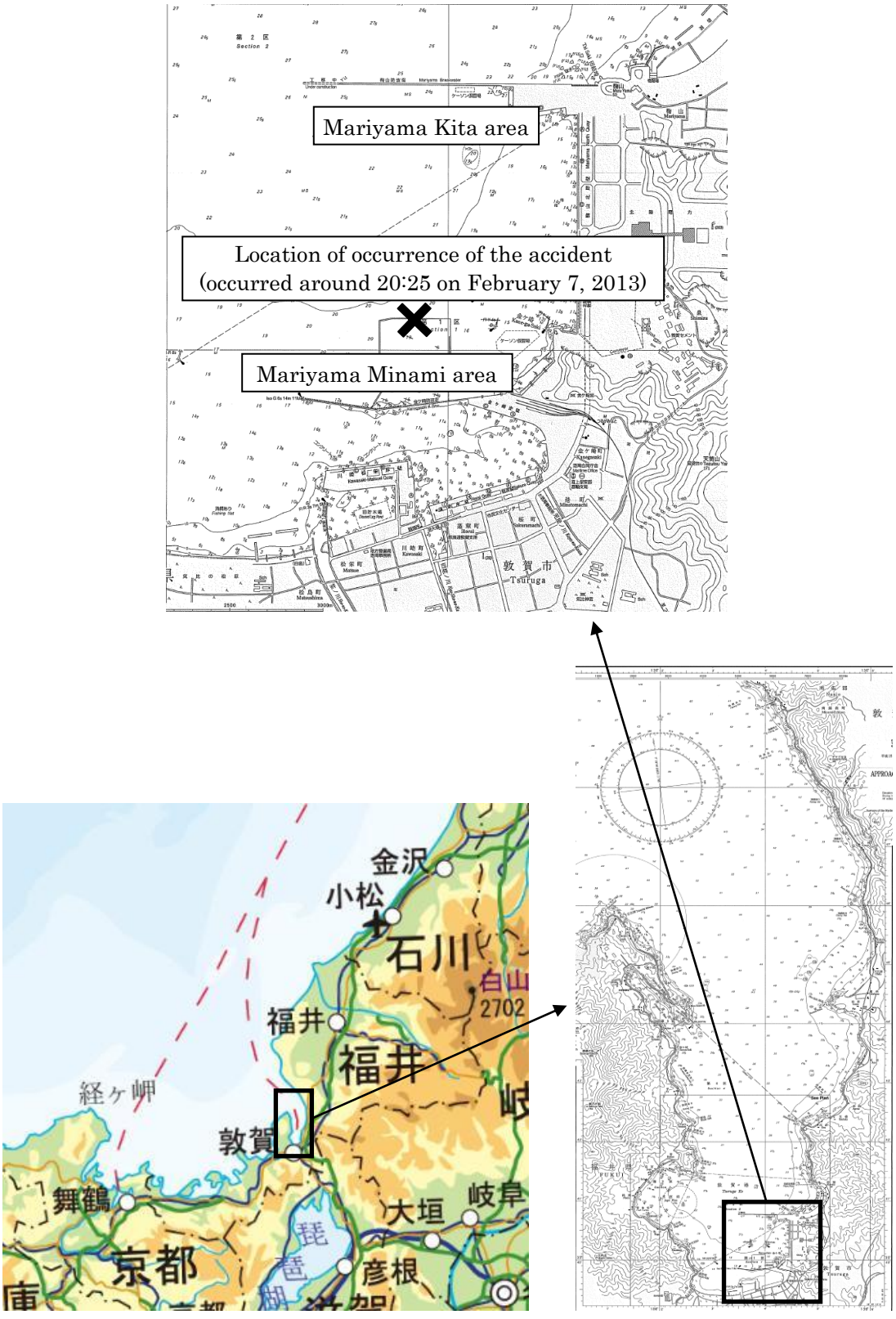
Preventive measures

1) Under adverse meteorological conditions, safer placement of the ship, such as refuge or anchoring, should be sought at the master's judgment instead of maintaining difficult berthing.
2) Necessary weather charts should be obtained beforehand to always be prepared for a quick response to meteorological changes.
3) As the weather quickly worsens on the western coast of Japan, special precautions should be taken, especially for those ports with a low breakwater that allows waves to easily enter during bad weather, such as Tsuruga Port.
4) Going near a rope or wire rope under tension should be avoided whenever possible, not only when operating the mooring winch and windlass but also when the ship is in the berth.
5) Crew members should always wear safety helmets, safety shoes and gloves when doing operations.
6) When someone is injured, help should be called for without delay and first aid for lifesaving should be applied.

5.2 Safety Actions Required

It is necessary for ships to leave the berth early to avoid severance of mooring lines due to movements of the ship caused by secondary undulation.

Appendix Figure 1 Location and Time of Occurrence of the Accident



From a 1/25,000 map published by the Geospatial Information Authority of Japan

Appendix Figure 2 General Arrangement of the Vessel