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An empirical study on the need for anchor operation education and training

Masashi Sugomori
World Maritime University

WORLD MARITIME UNIVERSITY
Malmö, Sweden

AN EMPIRICAL STUDY ON THE NEED FOR ANCHOR OPERATION EDUCATION AND TRAINING

By
MASASHI SUGOMORI
Japan

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: ....

Date: 30th August 2010

Supervised by: Daniel Seong-Hyeok Moon
Professor
WORLD MARITIME UNIVERSITY

Assessor: Raphael Baumler
Assistant Professor
WORLD MARITIME UNIVERSITY

Co-assessor: Stephen J. Cross
Professor, Director of Projects
MARITIME INSTITUTE WILLEM BARENTSZ TERSCHELLING

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ABSTRACT

Title of Dissertation: **An Empirical Study on the Need for Anchor Operation Education and Training**

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A large number of accidents in respect of anchoring operations have been reported by marine accident investigation bodies. Especially in the 2000s, the casualties involving oil pollution have been significant among such cases.

According to the trend of the peak gust observed in Japan, there is a tendency for it to be increasing year by year. In addition, the prediction of tropical cyclones says the size will also be increasing with the result that ships are expected to be exposed to stronger winds than before.

Research is being made on the current regulations for both technical and training requirements at the international convention level. However, this seems to be insufficient to prevent accidents occurring regarding anchoring operations.

Based on the statistical analysis of the accident cases using Quantification method type III, the major factors of accident are identified; that is a lack of education and training of the anchoring operation under severe weather conditions.

Further, a proposed syllabus on the anchoring operation is presented and discussed taking into consideration both the education and training aspects. Finally, the development of an anchoring simulator is suggested.

KEYWORDS: Anchoring, Education, Training, Syllabus

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List of Abbreviations

AB	Able-bodied Seaman, Able Seaman
COC	Certificate of Competency
FPSO	Floating Production, Storage and Offloading
IACS	International Association of Classification Societies
IPCC	Intergovernmental Panel on Climate Change
ISM	International Safety Management (Code)
JMAT	Japan Marine Accident Tribunal
MAIA	Marine Accident Inquiry Agency, Japan
MAIB	Marine Accident Investigation Branch, the United Kingdom
MET	Maritime Education and Training
NIST	National Institute for Sea Training, Japan
OOW	Officer of the Watch
SAIB	Swedish Maritime Safety Inspectorate
SMS	Safety Management System
SOLAS	The International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended in 1995 and 1997
TRB	Training Record Book

Chapter 1. Introduction

Accidents at sea never disappear although the International Maritime Organization and its member states have established new regulations to prevent the same kind of accidents happening again. As an example, the *Titanic* disaster in 1912 triggered the establishment of the SOLAS convention in 1914 (IMO, 2004). In the twenty-third session of the Assembly, the Secretary General, E. E. Mitropoulos (2003) said in his speech that:

> While our prime duty will be to act proactively to ensure that accidents do not happen in the first place, our work should also be directed towards ensuring that, once an accident has taken place, the system is there to minimize its impact on human lives, property and the environment.

In this light, the IMO should act proactively to ensure safe shipping and a clean environment. The purpose of this dissertation is to identify the facts behind anchor handling accidents and to make recommendations regarding maritime education and training to help prevent accidents in the future.

1.1 Importance of the Study

The accidents related to anchor handling have been reported by several maritime accident investigation organizations. Actually, some of them have been fatal accidents related to the loss of human life. It is generally said that the cause of more than 80 % of accidents at sea is the human factor. Nevertheless, when the accidents are examined, the competency in anchor handling seems to be the lack of competence of the seafarers at a certain level. A lot of accidents with anchor handling have happened under severe weather. In fact, there is no requirement on anchor handling training under severe weather as emergency training. In addition, an anchor windlass takes on the key role in respect of anchor handling because the operation of anchors is controlled by that as well as being used for the mooring winch.

Thus, the anchor windlass is a vital part of the ship's installation in allowing proper handling of the ship's ground tackle, and it is a most important aspect for the safety of the ship and crew (Vervloesem, 2009).

On the other hand, climate change today is being focused on. Over the last decade, extraordinary peak gusts have been observed due to the growth of the tropical cyclone in size. In addition, the prediction in the future on the size of tropical cyclones says that these will become bigger than before due to global warming. For this reason, ships may be exposed to stronger winds than before in the future.

In spite of the situation mentioned above, there have been few discussions on the education and training of anchor handling. There is, therefore, a need to review the current education and training program.

1.2 Objectives of the Study

The objectives of the study are as follows:

I. To examine anchor handling accident cases
II. To define the relevant regulations on anchor handling
III. To identify the causes of anchor handling accidents and their correlation
IV. To develop an anchor handling education and training syllabus

1.3 Order of Presentation

The order of presentation is composed in a logical way to achieve the objectives of this dissertation.

In Chapter 2, the background of the study is mentioned. The accident cases on anchor handling and the findings in several maritime accident investigation bodies are introduced. In fact, the accident casualties have been reported in the 2000s. In addition, the weather impact, especially a variation on peak gusts in Japan and the serious future prediction has been researched.

In Chapter 3, a characteristic of anchor windlass and regulatory bases on anchor windlass and requirements of education and training under the current situation are discussed.

In Chapter 4, the analysis of the accident data mentioned in Chapter 2 is presented by using a statistical method named Quantification Method type III. Before applying the statistical method, the classification of the accident was done by a group of experienced seafarers using the 5-M of the accident factors. The analysis identifies the relevance of each accident factor.

In Chapter 5, based on the analysis in Chapter 4 and current training requirement mentioned in Chapter 3, a model syllabus on education and training of anchor handling for seafarers is proposed. In addition, the implementation of anchor handling courses is discussed by being divided into on-shore and on-board education and training.

1.4 Scope and methodology

First of all, this study started from collecting the accident cases regarding anchor handling or dragging anchor as much as possible. The author was able to collect accident cases that had occurred in Japan. These accident cases are written in the publication of accident verdicts from Japan Marine Accidents Inquiry Agent. Second, the author asked the Maritime Accident Investigation Branch (MAIB), the United Kingdom and Swedish Transport Agency to provide accident cases on anchor handling and dragging anchor. They agreed willingly and even included unpublished information. Third, the author made contact with a person from South Korea to provide South Korean accident cases. Fortunately, these are available on the web site, but written only in Korean. The contact person, however, willingly provided the translated papers. In addition, the author found other accident cases in a publication from the Nautical Institute.

Furthermore, climate change is also highlighted. The statistics on peak gust at weather stations in Japan were analyzed to assess a trend.

Based on the accident data, the working group composed of experienced seafarers made a classification by using 5-M of accident factors. By using the classification, the author applied the Quantification method type III and examined those accident cases.

This study, therefore, intends to identify the cause of anchor handling accidents and how to implement a comprehensive anchor handling education and training.

Chapter 2. Background – Accident cases and weather impact

Many accident cases related to anchor handling and windlass operation have been reported over the years. In this chapter, the status of accidents on anchor handling is introduced. The author has focused on climate change from the past. Especially, the peak gust in several places in Japan has been researched and analyzed. Furthermore, as global warming progresses, the future prediction made by a research institute is also mentioned in this chapter.

2.1 Accident Reports on anchoring operation

The accident reports which are set out in this section are collected from several Maritime Accident Investigation Organizations such as the Japan Marine Accident Tribunal (formerly the Marine Accident Inquiry Agency, Japan.), the Maritime Accident Investigation Bureau (the United Kingdom), the Swedish Maritime Safety Inspectorate and the Korean Maritime Safety Tribunal. Furthermore, several incident cases are also been reported. The brief overviews of accidents which have occurred are given below in chronological order.

i. Cornhusker Mariner (7th July 1953)

An American steamer, Cornhusker Mariner was anchored at Pusan offing. After anchoring, a radio officer received a weather report about a typhoon. It was reported that a typhoon would be about 200 miles to the north of Pusan next early morning. The master concluded the typhoon was passing and would pose no threat. That was apparently overlooked by the master. However, the master left the oral order that the anchor was to be checked every 15 minutes and the master was to be called in the event of any change in the anchor bearings or weather. These orders were passed from one watch to the next. There were no written orders except general instructions in the chart room. As the wind and swell getting stronger, the third officer (OOW) did not notify the master on the weather change. Furthermore, the third officer did not stand by radar. When he used it, it took time to warm up. Even though he detected the dragging anchor, he never notified the engine room or the master. Due to his negligence, the ship was aground (Cahill, 2002).

ii. Donacilla (3rd October 1967)

A tanker, Donacilla (70,010 tons) anchored in the Thames estuary with three shackles. At that time, the wind was force 6. The engine was immobilized due to maintenance. Suddenly, a heavy squall struck causing the ship to start dragging. Although the chain was veered out and the other anchor was dropped, the ship was aground (Cahill, 2002).

iii. Wealkehy Trade (1st February 1969)

A general cargo ship, Wealkehy Trade (5,000 tons) was anchoring at Mutsure offing, Japan without anchor watch on bridge. The other anchoring vessel, Haeyang Ho's chief officer found that Wealkehy Trade and the other two ships collided lightly as Wealkehy Trade dragged her anchor. Subsequently, Wealkehy Trade was approaching toward Haeyang Ho with danger of collision. Although Wealkehy Trade started engine astern to avoid collision with Haeyang Ho, the ship continued to drag the anchor. Consequently two ships collided. The cause of the accident was the operational negligence of Wealkehy Trade on improper anchor watch (KMST, 1969).

iv. London Valour (9th April 1970)

A bulk carrier, London Valour (15,947 tons) anchored at Genoa offing, just outside of the breakwater for unloading her cargo to await the berth. The chain length veered in the water was not enough when the wind getting higher. The master neglected to pay out more chain. Although all crew were qualified and competent, the vessel started to drag her anchor due to high swell and strong wind. At that time, the main engine was maintained and the chief engineer was not notified to bring the engines to a state of readiness. Consequently, the ship was aground and sank alongside the breakwater without letting go the other anchor. 20 crew lost their lives (Cahill, 2002).

v. Canberra (14th August 1973)

A cruise liner, Canberra (44,807 tons) anchored at St. Thomas offing, the Virgin Islands. Although the master wrote the order book on strict anchor watch, the OOW notice late and not detect the anchor dragged immediately when a heavy squall struck. When the OOW informed the master, he notified the engineer to ready the engines. The master detected the anchor dragged when he came up to bridge. In spite of master's great effort with using of engines, the vessel was aground (Cahill, 2002).

vi. Yushio Maru (17th April 1976)

A cargo ship, Yushio Maru (1,995 tons) was approaching anchorage. The master of Yushio Maru found the other anchoring ship, Aroho (4,967 tons) was leaving anchorage. Yushio Maru anchored just only 150 meter from Aroho. After Yushio Maru anchored, the OOW looked out to check other ship condition under strong wind. When the master of Yushio Maru recognized Aroho was dragging anchor, he ordered to stand by crews and ready to use engine. However, Aroho collided with Yushio Maru. The cause of the accident was the operational negligence of Yushio Maru and severe weather because Yushio Maru was anchored closely from Aroho (KMST, 1976).

vii. No. 5 Yunam Ho (7th April 1977)

A log carrier, No.5 Yunam Ho (3,949 tons) anchored at Pusan South anchorage under strong wind and high swell. As many ships were anchoring at the area, the ship could not make an enough room for anchorage. For this reason, the ship veered 3 shackles of anchor cable with using engine continuously. However, due to strong wind and high swell, the ship started to drag her anchor. Consequently, the ship collided with the other ship. The cause of the accident was severe weather and operational negligence of the ship (KMST, 1977).

viii. No.2 Donam Ho (10th March 1978)

A general cargo ship, No.2 Donam Ho (1,998 tonnage) anchored at Pusan N2 anchorage to unload the cargo. As commenced the cargo work, the master and the chief engineer left the ship to shore. The duty officer found that the weather was getting worse. In order to prevent to dragging anchor, the duty officer ordered paying out one more shackle and tried to keep the position. Despite of the effort of preventing to drag the anchor, the weather was getting worse. The duty officer decided to stop the cargo work as well as reporting that situation to the company. Even though the engine was used variously by under his command, the ship dragged her anchor. Consequently the ship collided with the other anchoring vessel. The cause of the accident was the operational negligence of the ship under severe weather (KMST, 1979a).

ix. No.2 Dongmyoung Ho (27th August 1978)

A general cargo ship, No.2 Dongmyoung Ho (4,502 tons) anchored in Malaysia water to load the cargo. As suddenly the wind force increased to 9 BF, the duty officer reported to the master. The master ordered the engine ready. However, engine could not use properly and that ship started dragging her anchor. Consequently, the ship collided with the other anchoring ship. The cause of the accident was the operational negligence of Dongmyoung Ho. This ship should consider the situation under severe weather and also should be able to use the engine any time under any situation (KMST, 1979b).

x. Syogo Maru (23rd August 1982)

A cargo ship, Syogo Maru was approaching Pusan anchorage in order to anchor. Due to the severe weather, the master committed operational negligence and carelessness of watch keeping during approaching anchorage. Consequently, the ship collided with the other anchoring ship. The cause of the accident was an operational negligence of Syogo Maru. Syogo Maru should maintain a proper look out all the time by sight and hearing as well as by all available means appropriately in the prevailing circumstances and conditions. However, Syogo Maru did not have a sufficient look out properly (KMST, 1982).

xi. OSA Vigoroso (28th September 1983)

A Log carrier, OSA Vigoroso (6,500 tons) was under construction alongside at quay in M shipyard in Pusan. A typhoon was approaching to that area. Shipping company had decided to shift from quay to anchorage. 8 persons was onboard and anchored at M-0 anchorage. The problem of OSA Vigoroso was not under command due to no installation of engine compartment on the ship. While OSA Vigoroso started dragging her anchor, the crew could not handle the ship. Consequently, OSA Vigoroso continued to drag her anchor and collided with the other anchoring ship. The cause of the accident was an operational negligence and insufficient procedures for emergency situation under severe weather (KMST, 1983).

xii. Cahr Kwei (28th September 1983)

A general cargo ship, Cahr Kwei (12,185 tons) anchored at Pohang anchorage At that time typhoon was approaching. The ship started to drag her anchor but the engine was not used to avoid dragging. Consequently, the ship collided with the other anchoring ship. The ship did not take any action due to the observance of good seamanship in accordance with the Rules. At that time, there was no dragging ship in the vicinity of Cahr Kwei even though weather was severe. Taking into consideration of the circumstance, the ship had a problem on the anchor holding power. The cause of the accident was an operational negligence and a lack of positive action for emergency situation under severe weather (KMST, 1984).

xiii. Marine Bounty (13th January 1987)

A bulk carrier, Marine Bounty (57,561 tons) anchored at designated anchorage of Pohang offing, South Korea. This ship was aground due to stormy weather. Cause of the accident was 1) the OOW’s improper anchor watch which was monitored by using only radar, 2) the master’s overconfident to the weather and his shore leave and 3) Lack of proper standing order to the duty officer. This case was caused by operational negligence (KMST, 1988).

xiv. Oriental Ace (15th July, 1987)

Oriental Ace (3,963 tons) anchored at Yeosu offing, South Korea. Typhoon was approaching at that time. As it became strong wind and high swell, the master decided to escape offshore. He ordered to heave up anchor, yet the anchor was not heaved up due to relatively high air draft and strong wind and high swell although the engine was stood by. Consequently, the ship was aground and the fuel oil was leaked. The cause of the accident was 1) a choice of anchorage, 2) insufficient length of anchor cable (insufficient holding power) and 3) the master's improper operation when the anchor was heaved up (KMST, 1987a).

xv. Atlas Counselor (31st August 1987)

A bulk carrier, Atlas Counselor (12,771 tons) anchored at Pohang offing, South Korea with ballast condition. Typhoon was approaching at that time. As it became strong wind and high swell, the master veered out the anchor chain and stood by engine. Despite of the effort, the ship was dragging anchor and the master requested two tug boats in order to prevent to collide with a breakwater. However, the tug boats could not come out. Although the ship avoided a collision with a breakwater, it was aground to beach. The cause of the accident was not only due to severe weather but also due to the unskillful master's operational misjudgment on choosing proper anchorage to get an enough anchor holding power, taking in ballast water to reduce effect of wind force and an improper operation of anchor handling (KMST, 1987b).

xvi. Taisetsusan Maru (20th September 1991)

A container ship, Taisetsusan Maru (2,894 tons) anchored at Miyako offing (Northeast coast of Japan) to avoid the bad weather due to coming typhoon. When anchoring, the chief mate who was in charge of anchor handling at forecastle deck did not follow normal procedure of securing anchor chain. Although he applied its brake, he kept engaging the clutch and did not insert the pin for controller stopper. After a while, due to high swell and strong wind, the anchor chain bounded and subsequently the strong tension was taken to the hydraulic motor of windlass. Consequently, the motor was broken and that ship dragged the anchor leeward. Finally, Taisetsusan Maru collided with the other vessel, whose hull was damaged and whose crew got injured when they abandoned (Marine Accidents Inquiry Association, 1994).

xvii. Daishowa Maru (11th February 1992)

A wood-chip carrier, Daishowa Maru (48,566 tons) was anchored at Twofold Bay offing, the south coast of Australia. Although the weather was getting severer, the master did not decide to leave her anchorage to offshore. He had been well advised that his watch officers kept a close anchor watch. The watch officer (3rd mate) neglected to fix her position and detected the anchor dragged late. The relieved watch officer confirmed the ship shifted from original position. The master was called and the engine was stood by. The master ordered to heave up anchor with full-ahead engine. The tension of the chain was very tight and the windlass could not cope. Consequently, the ship was grounded (Cahill, 2002).

xviii. Korean Shipper (12th October 1994)

A semi-container, Korean Shipper anchored at Jinhae Bay, South Korea with full load condition. The typhoon was approaching at that time. The ship was aground due to strong wind and high swell. The cause of the accident was 1) negligence of the OOW on proper anchor watch, 2) late notification to the master on dragging anchor, 3) the master's mischoice of anchorage taken into account on loading condition, 4) lack of consideration of ship's draft against wind pressure and 5) improper operation on anchor handling (KMST, 1995).

xix. U.K. flagged Ro-ro Passenger ferry (1st March 1995)

A ro-ro passenger ferry, XX (18,523 tons) was carrying out the anchor operation in a harbour area under strong weather. Crew member (Deck ratings: Age 20-24) lost grip of windlass brake and struck gypsy guard. His grip was lost when another crew member attempted to speed up operation by assisting first crew member in his efforts to release the brake. Second crew member did not appreciate potential consequence of his actions. The first crew member got bruising injury. The cause of this accident was an issue on the working methods (MAIB, 2010).

xx. Panamanian Oil Tanker (1st January 1998)

An oil tanker, XX (17,134 tons) anchored with pilot onboard at Torbay, the United Kingdom. The master received a weather forecast indicating the on-shore wind would increase to gale force. He ordered the OOWs to call him and engineer officer when they suspected the ship was dragging anchor. After a while, the wind force reached to 9 and the OOW plotted her position and confirmed her dragging as he became aware the vessel was moving. The master came up to the bridge and he ordered to heave up anchor. However, due to the severe weather, the cable could not be shortened despite using full power on the engines to help. The ship continued to drag and grounded. There was no pollution and there were no injuries, yet this ship suffered the bottom damage (MAIB, 2010).

xxi. No.18 Kinko Maru (10th January 1999)

A product oil tanker, No.18 Kinko Maru (695 tons) was sailing in the passage toward her berth in port of Yokkaichi, Japan. Only first mate was standing at forward station. However, in spite of the stand-by condition, he left forward mooring deck briefly in order to take his jacket to his room without putting the controller stopper and no notice to the bridge. Subsequently, the applying power of the windlass brake was not enough and spontaneously the anchor chain was walked back. As a result, the submarine cable which was laid down on the seabed was hooked by the anchor and was destroyed (Marine Accidents Inquiry Association, 2001).

xxii. Ever Sea (19th March 1999)

A Panamanian general cargo vessel, Ever Sea (4,480 tons) anchored at Pohang offing, South Korea. The master did not obtain the weather forecast. The ship was aground without any engine use due to strong wind and high swell. The cause of the accident was 1) lack of weather information, 2) misuse of engine and improper operation of anchor handling (KMST, 2000).

xxiii. Happy Lady (21st January 2001)

A liquid petroleum gas (LPG) carrier, Happy Lady (6,107 tons) anchored at the designated anchorage in the Thames estuary. The starboard anchor cable was heaved up for berthing. At that time, no officer was on the forecastle (Chief mate came late to the forecastle deck) and cable leading was on the port bow. Then cable became trapped between the bulbous bow and the stem on several occasions. The cable leadings was not informed to the bridge properly (lack of communication) and The master attempted to clear the cable by maneuvering the vessel, yet the anchor dragged in the strong wind (Lee shore situation). Consequently this ship grounded on soft mud on a falling tide (MAIB, 2001).

xxiv. Willy (1st January 2002)

A product oil tanker, Willy (3,070 tons) anchored at Cawsand Bay, the United Kingdom. The ship was exposed to strong south easterly wind with pitching due to her light condition and the swell (Lee shore situation). At that time, the amount of cable used was insufficient given the prevailing weather conditions, depth of water, nature of the seabed and condition of the ship. The OOW did not detect the ship’s movement and the anchor dragged immediately (improper anchor watch) and then the master was not informed until about seven minutes after the anchor had started to drag. Furthermore, the OOW did not start the main engine until the master ordered, yet the engine could not be started and there was not sufficient time to avoid the danger. The master did not consider paying out the additional cable to stop anchor from dragging. Eventually this ship grounded. No one injured (MAIB, 2002).

xxv. Cope Venture (25th July 2002)

A panamax type bulk carrier, Cope Venture (36,080 tons) left her birth in port of Shibushi, Japan due to approaching the typhoon and expected to be severe weather. The master decided to anchor just off the port. He was told that this area was not good area to evacuate from typhoon because this area in Shibushi Bay is opening to the Pacific Ocean. It meant the swell would be coming directly from typhoon. As typhoon approaching, the wind and swell became bigger. The master let the chief mate station on the forecastle and let report the cable leadings as the engine was been using in order not to drag anchor. In despite of the effort, the ship started to drag the anchor. Then the master decided to heave up anchor but it was impossible to do it due to strong wind and high swell. As a result, the ship was grounded and four crew members died when they evacuated from the ship (Marine Accidents Inquiry Association, 2003).

xxvi. No. 1 & No. 2 Haedong Ho (12th September 2003)

A combined pusher barge, No. 1 & No. 2 Haedong Ho was anchored under severe weather due to approaching typhoon. That ship was dragging anchor and approached to a training ship H. The master of the training ship recognized a danger and noticed to No. 1 & No. 2 Haedong Ho to avoid a collision through VHF He asked to keep enough distance from the ship and noticed an awareness of being dragging of No. 1 & No. 2 Haedong Ho. No. 1 Haedong Ho replied that the ship was not under command due to out of order of the port side engine. In order to avoid collision, the training ship was requested to keep distance from No. 1 & No. 2 Haedong Ho by using engine ahead to passing on the stern side of the training ship and veering out anchor cable more than before. At that time, the wind was extremely gain strength, from 23-33 m/s to 44-46 m/s. Subsequently, No.1 & 2 Haedong Ho failed to control ship's engine and collided with the training ship. The cause of the accident was losing anchor holding power and dragging anchor under heavy weather. In addition, No.1 & 2 Haedong Ho committed operational negligence and lack of positive action in advance of dragging anchor. Even after finding dragging anchor, ship was not fully prepared to prevent collision through all available means appropriately in the circumstances and conditions (KMST, 2005).

xxvii. Ace (21st September 2003)

A general cargo vessel, Ace (16,143 tons) anchored at Pusan offing, South Korea. The master left the ship temporarily and the relieved master was commanding the ship during anchoring. The OOW had an improper anchor watch such as no anchor watch personnel on the bridge and not fixing anchor position. As the OOW did not notice the anchor dragged, the ship was aground although the engine was stand-by and was used. The cause of the accident was 1) the relieved master's negligence on proper command, 2) improper anchor watch, 3) the insufficient length of anchor chain in the water and 4) lack of safety management system of operating company (KMST, 2004).

xxviii. Sunflower Kirishima (9th October 2003)

A ro-ro car ferry, Sunflower Kirishima (12,418 tons) was sailing in the coast off

Shikoku, Japan. Due to the rough sea condition, the starboard anchor and its all chain (300m) were dropped into the sea and the anchor could not be hove up by windlass power. Consequently, the schedule of the ship was delayed. The causes were 1) a damage of the pin for controller stopper due to its modification and rough sea condition, 2) the severed wire stopper due to using less diameter wire for convenient work, 3) inadequate applying power for windlass brake and 4) inadequate safety education for the operation company (Marine Accidents Inquiry Association, 2004).

xxix. No.18 Seifuku Maru (22nd March 2004)

A product oil tanker, No. 18 Seifuku Maru (199 tons) anchored at Oita offing, Japan. The low pressure system was approaching to that area. At that time, strong wind and high wave were expected according to the weather information. However, as the master understood this vessel had never dragged her anchor under the condition, he did not pay attention to the anchor bearings. Furthermore, as he did not obtain the correct weather information, he did not pay out the additional anchor chain into the water. When he made round the ship, he felt unusual shock. He found the vessel was dragging the anchor. He tried to use the engine and order the anchor operation. Consequently, the ship was aground (Marine Accidents Inquiry Association, 2005).

xxx. No.28 Matsushima Maru (7th September 2004)

A general cargo vessel, No. 28 Matsushima Maru (455 tons) anchored at Saiki offing, Japan in order to evacuate from the approaching typhoon. The OOW detected the anchor was dragged due to strong wind. The master decided to drop her anchor at another position because the lee shore was very close. The ship anchored again with both anchors, yet the distance to another anchoring vessel was close. The master decided heave up the anchors again and he ordered to heave up both anchors at the same time. Subsequently, although the ship was using her engine, the blackout was taken place. Consequently, the ship dragged her anchors and collided with the anchoring vessel (Marine Accidents Inquiry Association, 2005).

xxxi. Kaiwo Maru (20th October 2004)

A sail training ship, Kaiwo-Maru (2,556 tons) anchored at Toyama offing, Japan. The master decided to continue to anchor there although the strong typhoon was coming (Lee shore situation). As the wind and swell was getting severer and severer, the master decided to pick up anchor and to evacuate to offshore. By the way, the winding power of the windlass was not enough under the severe weather although the engines were used. Subsequently the anchor could not be hove up and the ship has no choice. Finally it dragged anchor and ran aground. As a result the ship hit with the break water and the hull and all the part of ship were damaged. Fortunately no one was killed, yet 29 people injured. The causes of this accident were 1) miss-choice of an anchorage, 2) missing of an opportunity to evacuate, 3) lack of supporting framework from operating institute (Marine Accidents Inquiry Association, 2005).

xxxii. Marine Osaka (13th November 2004)

A general cargo ship, Marine Osaka (5,565 tons) anchored at Ishikari offing, Hokkaido, Japan. Due to the strong wind and high wave, the ship dragged its anchor. In spite of picking up its anchor, the ship drifted and hit to the break water because the propulsion power was not be enough due to bad weather. Subsequently, the ship was broken into three parts and sank. As a result, seven crew including master was killed because of the drowning. The causes of this accident were 1) wind pressure was big due to ballast condition, 2) inadequate anchor chain length in the water and 3) improper anchor watch and late recognition of the dragging anchor (Marine Accidents Inquiry Association, 2005).

xxxiii. POLO M (23rd November 2004)

A bulk carrier, POLO M (21,630 tons) anchored at Gotland offing, Sweden for loading her cargo. The intense low pressure system was passing through that area. The OOW detected the ship was dragging due to strong wind (10-11 BF). Despite of using engine, the anchor chain was not able to be heaved up due to tight chain. Consequently, the ship was aground. The cause of this accident was the strong wind and the inadequate fixing of anchor position (SMSI, 2005).

xxxiv. UK flagged tanker (16th December 2005)

A tanker, XX (16,754 tons) was sailing in high seas. The ship encountered heavy weather with heavy rolling and pitching. Then the starboard anchor wire stopper broke due to rough sea condition and the starboard anchor went slack as the windlass brake was weak. Consequently the anchor strongly impacted the hull and caused penetration cracks and dents. The causes of this accident were 1) the windlass brake had not been properly adjusted, 2) the anchor holding wire strop was not the correct size and not strong enough and 3) anchor chain compressor bar (stopper) was not fitting correctly with the pin not applied. The manager also identified that poor seamanship and lack of attention to duty along with a failure of the planned maintenance system (windlass brake adjustment and wrong wire strop fitted) were causes of this incident (MAIB, 2010).

xxxv. U.K. flagged container (2nd January 2006)

A container vessel was planning to anchor at an anchorage off Genoa, Italy. The depth of water was 59m. The master ordered to let go anchor after standing by at 2 shackles on deck walked back. After letting go the anchor, the master was reported 6 shackles were on deck. Subsequently, the master ordered the cable veered out to 7 shackles on deck. However, the anchor chain was veered out to the bitter end and the anchor chain was lost.

The cause of this accident was due to poor marking of the cable (marked correctly but not clearly), pins securing the bitter end was not enough to hold the cable (MAIB, 2010).

xxxvi. Bermuda flagged ro-ro passenger ferry (30th April 2006)

A ro-ro passenger ferry, XX (10,957 tons) was in the process of anchoring at Northern Irish offing under the calm sea condition. The AB was ordered to apply the brake as the cable was veering out very quickly. However the AB loosened the brake further in error and the cable took charge. The cable eventually reached to the bitter end and pulled free from the chain locker and fell into the sea. The cause of the accident was inadequate training of the AB and lack of communication or co-ordination (MAIB, 2010).

xxxvii. **Thunder (9th August 2006)**

A general cargo ship, Thunder (1,559 tons) anchored in the Wild Road anchorage off the port of Mostyn, the United Kingdom. Three shackles of cable were veered in 24m of water. The wind was gusting to 29 knots and a tidal stream of 2.5 knots was running. The vessel dragged her anchor overnight and then grounded. The causes of the accident were 1) Improper anchor watch by OOW, 2) Insufficient length of the anchor cable veered in the water, 3) No action in despite of the situation under BF 6 and strong tidal stream, 4) This ship did not have an appropriate chart (MAIB, 2006).

xxxviii. **Bahamas flagged Aframax crude oil carrier (13th August 2006)**

A crude oil carrier, XX (62,929 tons) anchored at Tees Bay, the United Kingdom. Although it was severe weather condition (Wind Force 7-9), this ship could not move from the anchorage due to hydraulic failure of windlass. The ship needed to call the service engineer and the necessary spares and needed to use her engines to maintain her position. The ship completed repairs with outside assistance and started to sail without further incident (MAIB, 2010).

xxxix. **Giant Step (6th October 2006)**

A bulk carrier, Giant Step (98,587 tons) anchored at Kashima offing, Japan. The severe weather was expected because typhoon was approaching at that time. As the wind was getting severer, the master decided to pick up anchor to evacuate to offshore. However, the anchor could not be picked up due to the leakage of hydraulic oil of windlass. While immediately the part was repaired, the ship was dragging anchor. The captain tried to use engine to prevent drifting. Eventually, the engine was stopped due to scavenge fire by high loading operation. The master ordered the chief mate to cut the anchor chain to sail because the anchor cable could not be hove up due to high wind and rough sea. Although the anchor chain was cut, the ship was drifting leeward because the engine power was inadequate. Finally, the ship ran aground and was broken into two parts. As a result, eight were killed and two were missing (Marine Accidents Inquiry Association, 2007).

xl. BRO ATLAND (20th January 2007)

An oil and chemical tanker, BRO ATLAND (11,377 tons) was anchoring. When the anchor was picked up, the green seas washed off the mooring deck due to high swell. Chief mate got the wave and drifted. He got injury. Obviously, this incident was due to human factor (Swedish Transport Agency, 2010).

xli. U.K. flagged container (2nd March 2007)

A Panamax container, XX (51,931 tons) was sailing for Harwich, the United Kingdom. That vessel lost the anchor on its way in the port area. The cause of this accident was failure of a windlass brake due to maintenance issues (MAIB, 2010).

xlii. Young Lady (25th June 2007)

A crude oil tanker, Young Lady (56,204 tons) anchored at Tees Bay, east coast of the United Kingdom. As the weather condition got severer, the ship stared to drag her anchor. The master decided to weigh anchor and depart. However during the operation, the windlass hydraulic motor exploded and the cable ran out to the bitter end due to high tension of the chain. The ship continued to drag when passing over gas pipe line. Consequently, the anchor flukes snagged the pipe. Fortunately, no one injured and there was no pollution. The cause of this accident is that the master was aware that the anchorage was not recommended in the forecast conditions and the decision to remain at anchor was inappropriate (MAIB, 2008).

xliii. Astral (10th March 2008)

A chemical and oil tanker, Astral anchored at Nab Anchorage, south coast of the United Kingdom. The weather deteriorated as the wind increased to BF 10 and this ship started to drag (Lee shore situation). OOW informed to the master and requested the main engine ready. Then the master came up to the bridge and dispatched the anchor party forward. The master tried to use the engine in order not to drag. In despite of their effort, this ship continued to drag to shore and grounded on the Princessa Shoal. No one injured, yet the there was structural damage for rudder, steering gear and hull. The causes of this accident were 1) inappropriate action by OOW and 2) insufficient time for main engine readiness (Swedish Accident Investigation Board, 2008).

xliv. Liberia flagged bulk carrier (4th October 2008)

A bulk carrier, XX (86,192 tons) was to anchor at off Immingham, the United Kingdom. The sea condition was very rough with wind gusting 7 to 9 in force. The vessel walked back 5 shackles and the windlass hydraulic motor disintegrated. Subsequently, the anchor cable rapidly ran out. The crew managed to arrest the running anchor cable at 8 shackles using the windlass brake and bow stopper. Due to the damage to the windlass, this ship was not able to heave up the anchor. The crew slipped the anchor at 8 shackles and attached two buoys to allow recovery when leaving the anchorage. The cause of this accident seems to be a machinery failure but MAIB analyzed the human factor is also involved due to anchoring under the severe weather (MAIB, 2010).

xlv. Bahamas flagged chemical tanker (15th January 2009)

A chemical tanker, XX (27,997 tons) anchored at Welsh offing. The master decided to heave up her anchor and drift till the weather abated. The cable slipped on the gypsy due to a heavy swell which caused the windlass to seize up. The ship could not heave or lower the cable and the master decided to continue to anchor (MAIB, 2010).

xlvi. Stella Voyager (23rd March 2009)

An oil tanker, Stella Voyager (58,088 tons) anchored at Tees Bay, east coast of the United Kingdom with starboard anchor. As the wind was getting stronger, the master decided to heave up the anchor. However, the tension of the chain was very strong it was hard to heave up the chain under the strong wind. Suddenly, the hydraulic motor was exploded although the safety devices were equipped and the bosun, who was operator, got a serious injury with a large fragment of the hydraulic motor (MAIB, 2009). While the cause of this accident is a catastrophic failure of the windlass and might not be related to the human factor, this happened under unusual situation (strong wind and high swell).

xlvii. Canada flagged FPSO (15th September 2009)

A FPSO, XX (108,222 tons) was sailing in the UK waters. It is noticed that the anchor had become slack in the hawse pipe. Crew were instructed to heave in and secure anchor, but operator failed to engage the clutch on the windlass before loosening the brake. Anchor and cable were lost overboard. This cause was the windlass operator's error (MAIB, 2010).

2.2 Research in Japan

In 2004, 10 typhoons hit Japan and 35 crew were killed or missing as a result. The number of landings in 2004 was the worst ever recorded in Japan.

In 2005, the Japan Marine Accident Inquiry Agency (MAIA) (present: JMAT and Japan Transport Safety Board) made a questionnaire research on the evacuation from the typhoons and collected these from 871 domestic vessels of over 100 tons. When the typhoon came, the number of anchoring vessels which sheltered from the typhoons was 690. The 122 vessels among the 279 vessels which used the main engine dragged their anchor. This means 43% of the vessels used the main engine. Fortunately, these vessels did not result in any accident while those anchors were being dragged. The masters of these vessels managed to control the ships well by keeping a strict anchor watch such as fixing the position frequently and detecting the dragging of the anchor immediately (MAIA, 2005).

2.3 Statistics and analysis in the UK

MAIB mentioned in an accident report that there have been 18 accidents in UK waters that are related to vessels dragging their anchor and subsequently groundings since 1992. A further 14 hazardous incidents have been recorded that these vessels were dragging their anchor but did not go aground. In addition to the statistics, MAIB remarked that the key factors to the groundings were 1) choice of anchorage, 2) the cable length veered in the water, 3) weather conditions and 4) main engine readiness (MAIB, 2006).

Furthermore, MAIB (2006, p.28) analyzed that almost all accidents where the vessels subsequently grounded had some common contributory factors as follows:

- The anchorage had often been chosen against the master's better judgment, given the prevailing or the forecast weather conditions and the proximity of a lee shore.
- In many cases the scope of the cable in the given depth of water was substantially less than the minimum recommended.
- Only when the OOW had determined that the vessel was dragging, was an attempt made to veer more cable. Several groundings would probably have been avoided had the master thoroughly assessed the forecast weather and veered more cable before the vessel started dragging.
- The amount of cable used might not have been sufficient in itself to prevent a vessel dragging, but in many of the cases the main machinery notice of readiness was inadequate for the crew to deal promptly with the consequence once the vessel began to drag.
- On several occasions, monitoring of the vessel's position within its predicted swinging circle was inadequate, and therefore did not provide early warning to the OOW that the anchor had begun to drag.

2.4 Summary of cases

To summarize the cases, 39 of 47 the accident cases mentioned in 2.1.1 above happened during severe weather. Especially significant is that the ships tried to heave up the anchor after detecting the dragging anchor but this seemed to be impossible due to the heavy tension of the chain, according to the investigation report.

2.5 Meteorological Statistics and Prediction

Global warming has been focused on in recent years, mainly derived from the emission of carbon dioxide (CO_2). Global warming makes a serious impact on the environmental side effects. Reducing CO_2 is an urgent task for all industry including shipping. However, climate change is not to be ignored for ship's operation. In this section, climate change and the future prediction made by the Japan Agency on for Marine-Earth Science and Technology (JAMSTEC) on wind force is referred to. In fact, ships at anchor are influenced by wind force although the current and the wave (swell) are also contributed. In particular, the meteorological statistics in Japan, as a sample of peak gusts which Japan Meteorological Agency has issued, has been analyzed.

2.5.1 Climate change at sea – cases in Japan

The Japan Meteorological Agency publishes the weather statistics on its web site (http://www.jma.go.jp). According to the data, the statistics on peak gusts have been collected randomly from several points in Japan. Sampling is mainly from coastal weather stations and covers all regions in Japan as in Fig. 1. Totally, the statistics of 21 points of peak gusts in the year are collected from 1967 to 2009 (some of them are not available) and plotted in the following figures (see Fig. 2, Fig. 3 and Fig. 4). Furthermore, in order to analyze the statistics and to observe the trend, the linearization is overlaid on each figure. To draw linearization on each graph, the Microsoft Excel function was used. As a reference, the raw data is shown in Annex I.

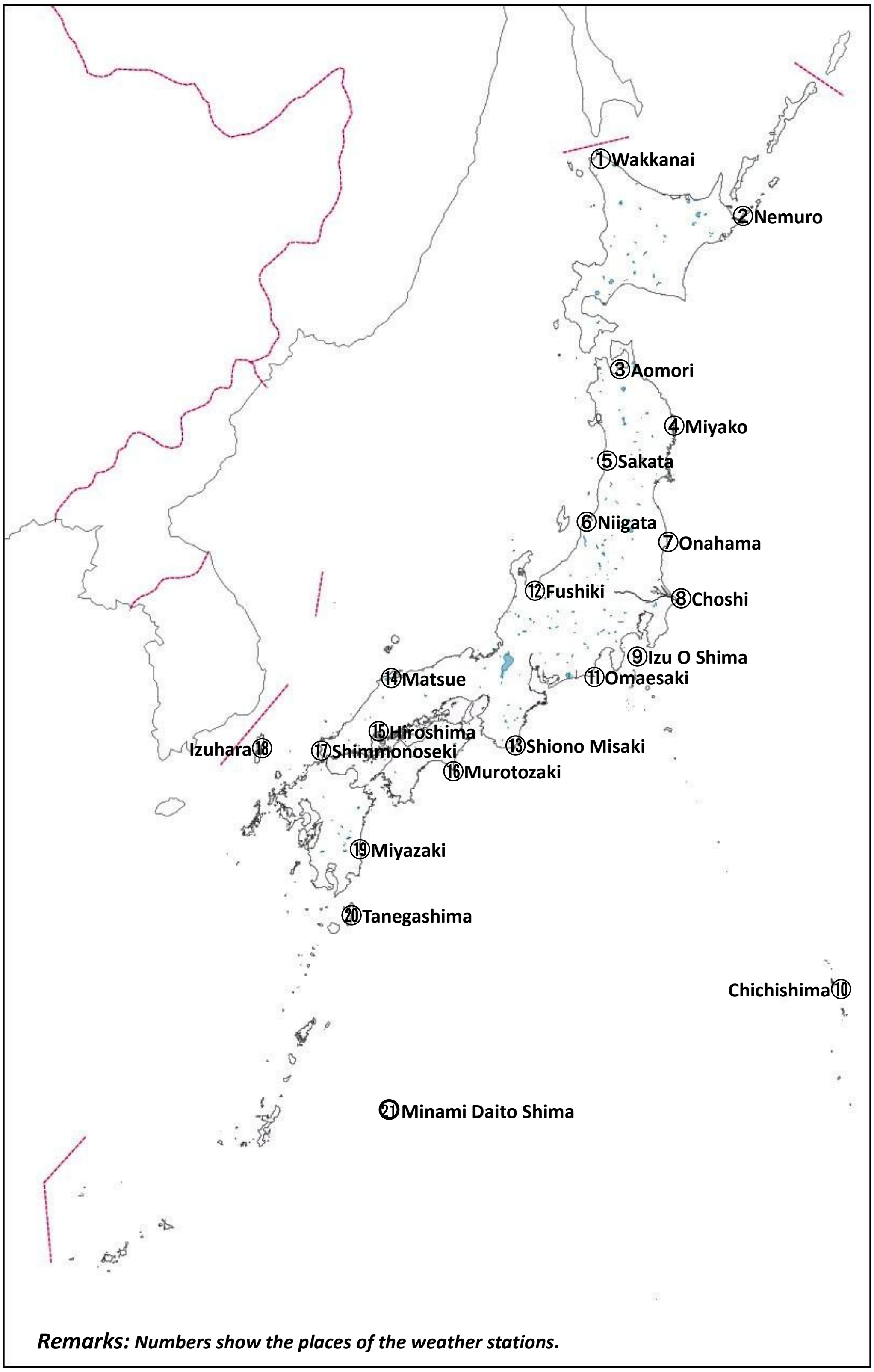


Fig. 1 Distribution of the sampling weather stations, Japan

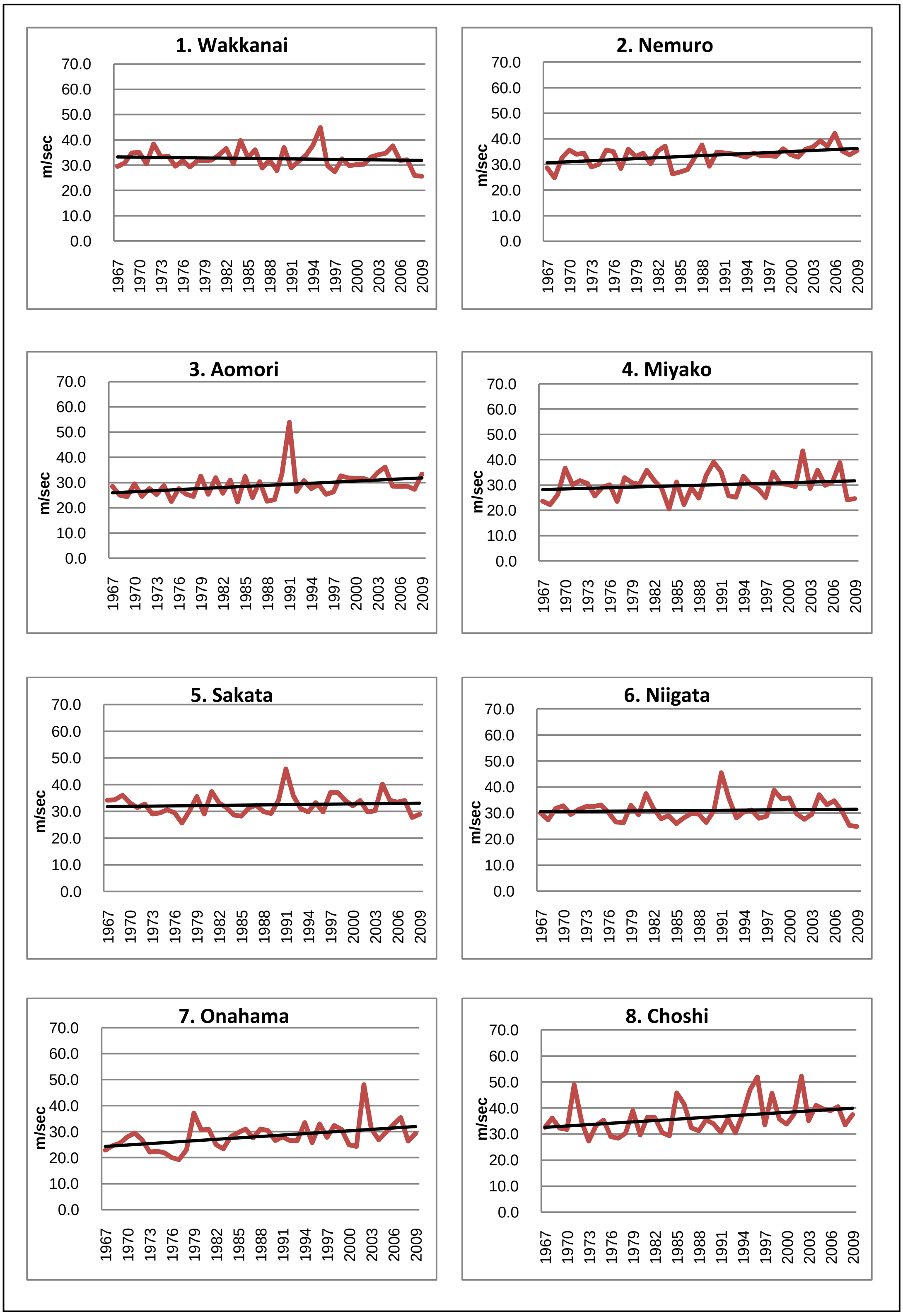


Fig. 2 Peak gusts at weather stations in Japan from 1967 to 2009 and linearization – part 1

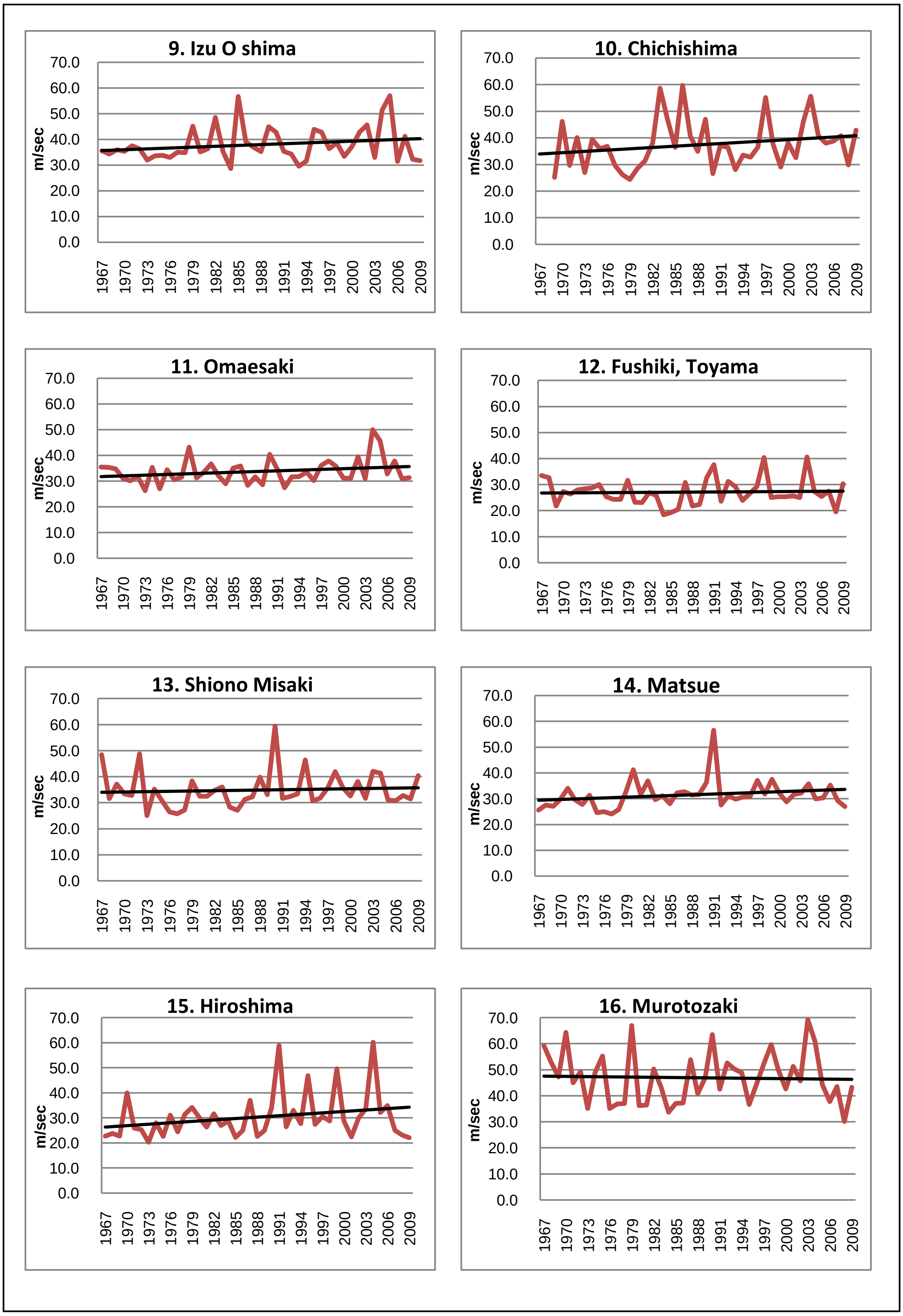


Fig. 3 Peak gusts at weather stations in Japan from 1967 to 2009 and linearization – part 2

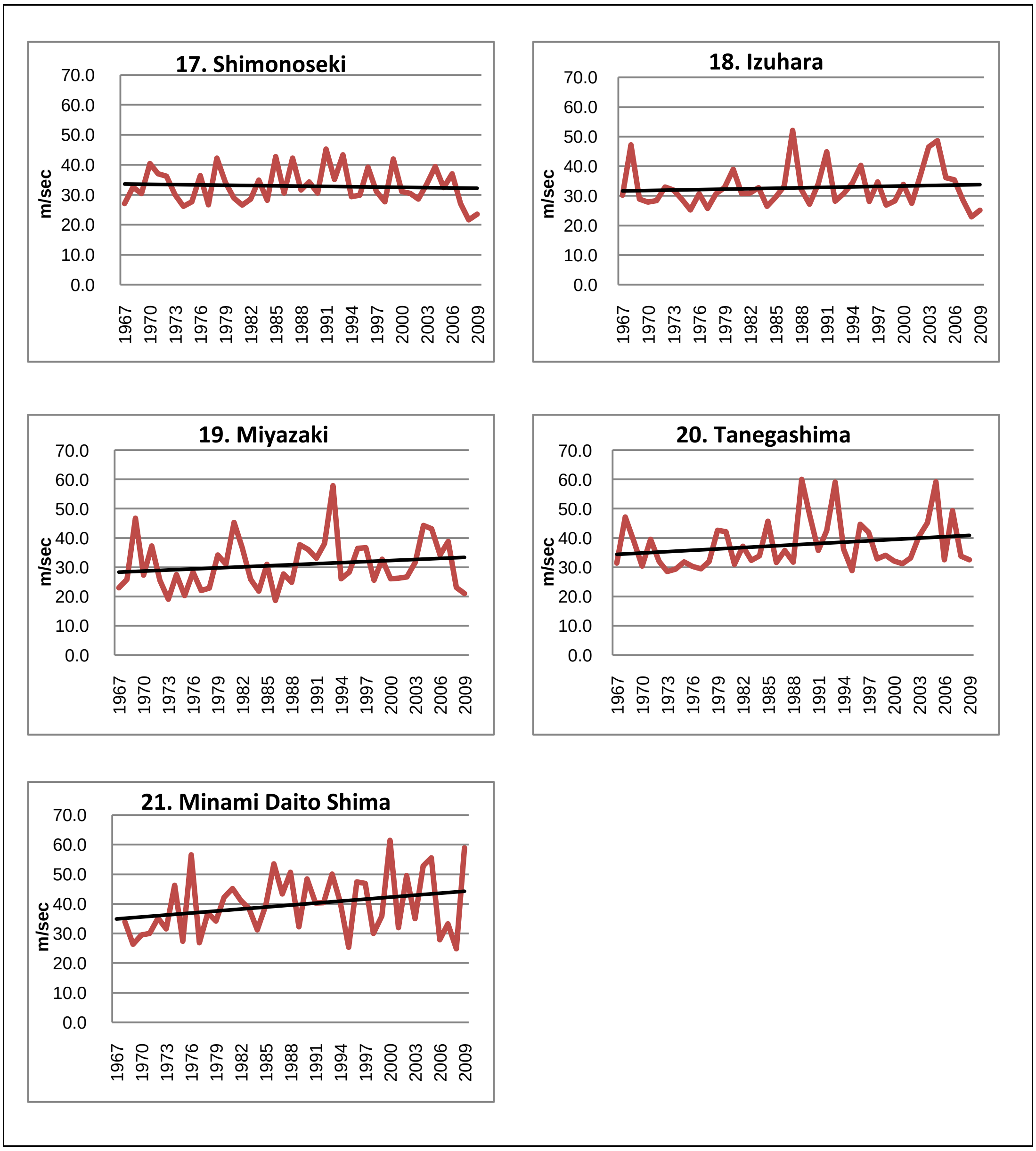


Fig. 4 Peak gusts at weather stations in Japan from 1967 to 2009 and linearization – part 3

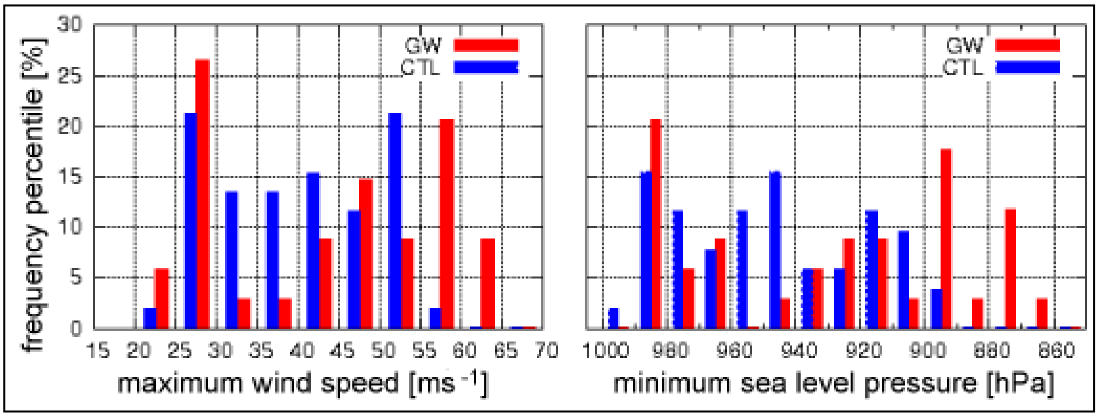
According to the linearization of the figures mentioned above, at 18 of 21 points the trend of the peak gust is increasing year by year. However, the trend of 3 of 21 points (Murotozaki, Wakkanai and Shimonoseki) has declined. This means the weather condition, especially wind speed, has been getting more severe. There are several areas which have suffered from tropical cyclones. Obviously

Japan is no exception, yet the seasonal low pressure systems may be getting more severe and influences there.

2.5.2 Future prediction on the generation of tropical cyclone

According to the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (2007), it is reported that the number of tropical cyclones will be decreasing due to global warming at the end of the 21st century, but their intense category will be increasing. The credibility of this report is, nonetheless, not high at that moment.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and the University of Tokyo have made a simulation experiment by using a super computer named *Earth Simulator* where they proved the above prediction in the IPCC-AR4 in April 2010. According to the report, the frequency of the maximum wind of the tropical cyclone and minimum sea level pressure will change as shown in Fig. 5. The CTL shows the data derived from an experiment on the current climate and the GW (Global Warming) shows future predictions under global warming (http://jamstec.go.jp/e/about/press_release/20100422).



Source: JAMSTEC

Fig. 5 Comparison between current and future prediction on tropical cyclone

In the future, it is predicted that the frequency percentile of more than 55m/sec in maximum wind speed is approximately 29% compared with approximately 2% in the current situation. In addition, according to the figure on the right, it is found that a frequency percentile of less than 900hPa of the minimum surface pressure of tropical cyclone is approximately 35% compared with approximately 3% in the current situation.

Based on this experiment, it is expected that vessels would be exposed by more severe winds and higher waves in the future if global warming continues to grow.

2.6 Summary

In this chapter, the accident cases related to anchor handling have been introduced. In addition, the climate change effects on peak gusts in Japan have been researched. It is proved that the peak gust at 18 of 21 points at weather stations in Japan has increased. Furthermore, the research made by a research institution in Japan shows the significant future predictions regarding tropical cyclones. If this trend continues in the future, ships would be exposed to much stronger winds than in the past.

However, in spite of a lot of serious incidents making human life hazardous and endangering the environment, no proper measures have been taken. In fact, despite the ISM code entering into force to reduce human error, serious accident cases have been significant in the 2000s. This is partly due to a lot of tropical cyclones (typhoons) that landed in Japan in 2004.

Why have these things happened? Why does the windlass not heave up an anchor under the strong tension of the chain? What is the performance requirement of the anchor and anchor windlass? What is the MET requirement under the STCW convention regarding anchor handling? In the next chapter, the requirements of international regulations regarding the anchor windlass will be discussed.

Chapter 3. Characteristics of windlass and regulatory bases of education and training on anchor handling

The regulatory bases on the anchor windlass are mentioned in this chapter from both the training and technical points of view. A general picture of the anchor windlass is mentioned followed by the regulatory basis.

3.1 Characteristics of anchor windlass

The anchor windlass is one item of the deck machineries which the ship uses for mooring, anchoring and cargo handling operations. There are several kinds of deck machinery on-board ships such as anchor windlass, mooring winch and deck crane. Mainly there are two types of deck machinery while there are other types of systems such as the steam powered system. One is an electric motor type and the other is a hydraulic motor type, although a deck crane uses hydraulic cylinders instead of hydraulic motors. However, the only type of motor is basically different between these two systems. Especially, for inflammable substance carriers such as oil tankers the electric motor system is not able to be equipped.

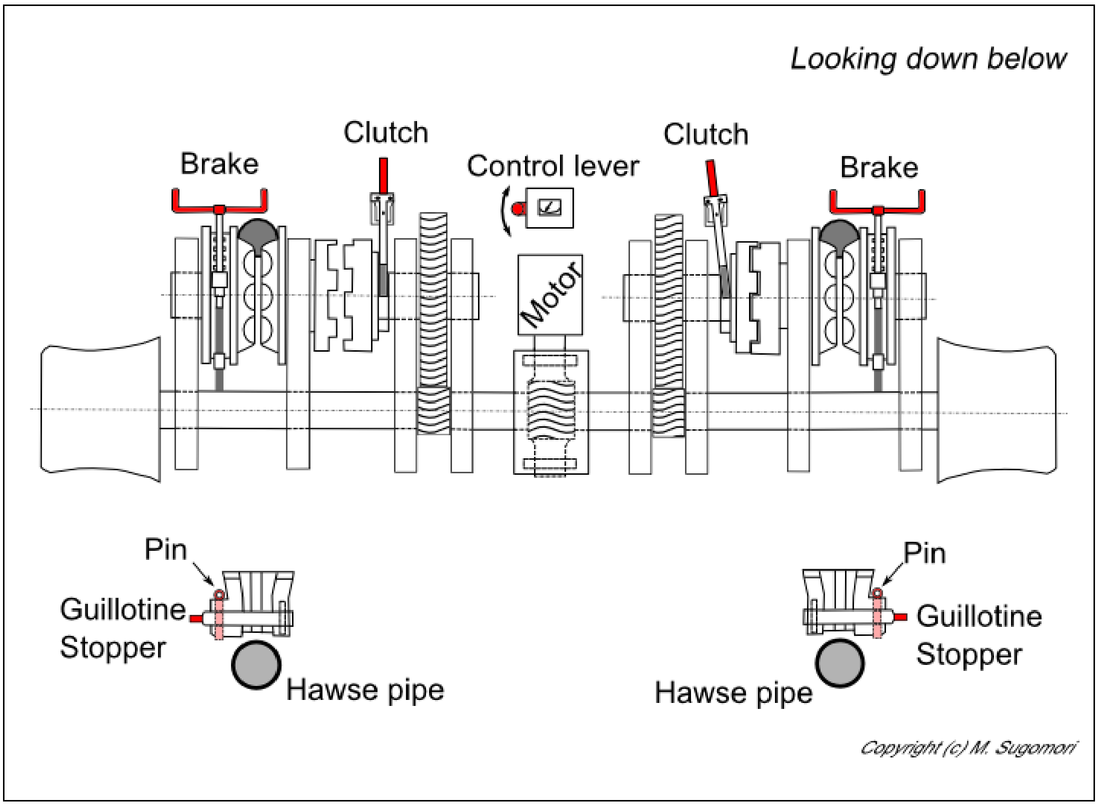


Fig. 6 Rough sketch of anchor windlass

Fig. 6 shows a rough drawing of the anchor windlass system. This is a very simple machine because there are only four operation points in an anchor windlass: Control lever, Clutch (Gear), Brake and Stopper (Guillotine). In addition to the four operation points, there is a lashing device for the anchor stopper, but it is only used for sailing in high seas or under rough sea conditions.

3.1.1 Electric motor system

On the electric motor system, electric motors with electromagnetic brakes are fitted as a driving force generator. Fig. 7 shows this system. Characteristically, a torque limiter is equipped between the motor and main propeller shaft in order to release the overload. For this reason, a torque limiter needs a proper torque setting of mating surface periodically. Otherwise the windlass does not make the proper performance as the manufacturer had intended. As mentioned in Chapter 2, the maintenance of the torque limiter may be a very important factor.

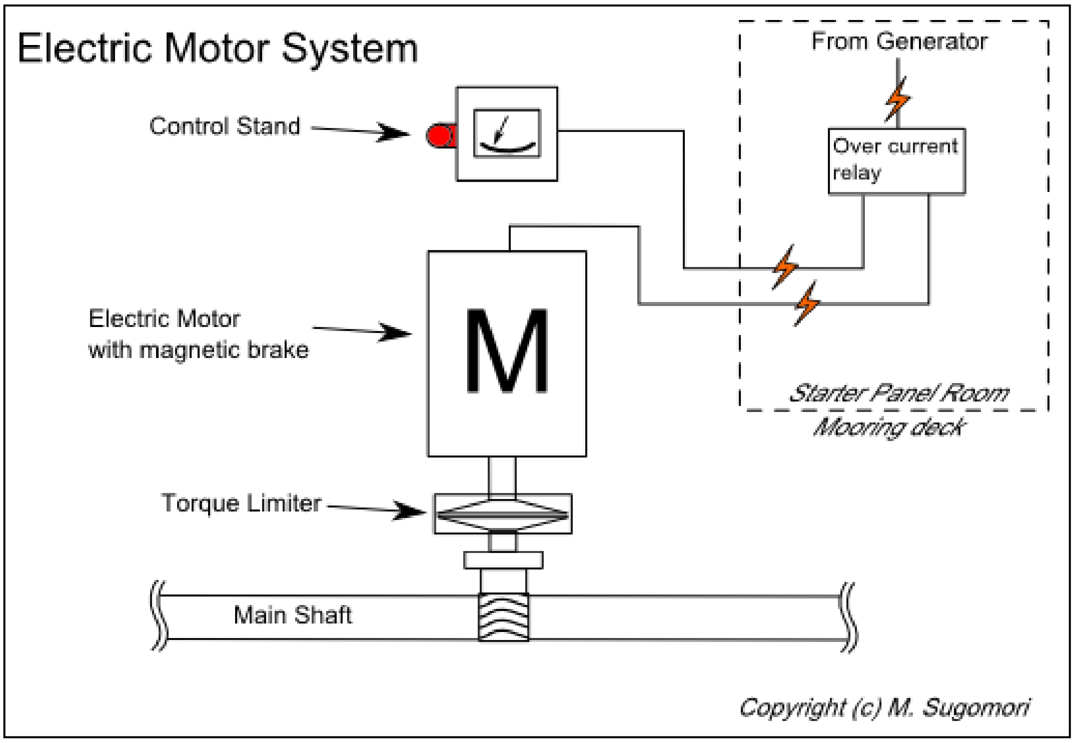


Fig. 7 Electric motor windlass

However, the brand-new electric motor type does not have a slipping clutch. It has just an over current relay and similar devices to avoid the overload. This means that the electric motor type of windlass is free from maintenance.

3.1.2 Hydraulic motor system

In contrast, this system uses operating hydraulic oil which is pressured by hydraulic oil pumps. The merit of this system is that no matter what the ship's size is, it can be applied. Furthermore, it can prevent the electric spark vicinity of the deck machinery because the hydraulic pumps and oil tank can be located apart from the deck machinery. Fig. 8 shows the drawings of this system. A control lever can control the speed of the winding by changing the flow of hydraulic oil. As a difference, there is a safety device called the Counterbalance valve to release the overload. This is a releasing valve which prevents the rising of the pressure of the hydraulic oil. It is necessary to maintain the settings periodically.

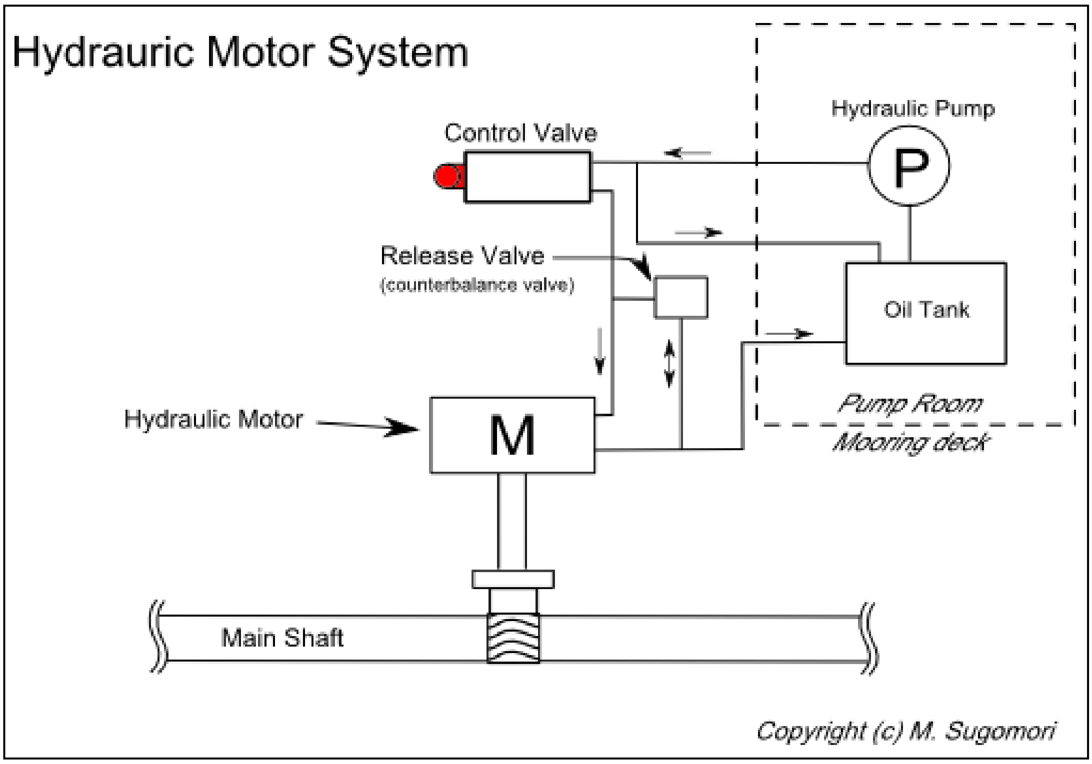


Fig. 8 Hydraulic motor windlass system

3.2 Technical requirements of an anchor windlass

In fact, there have been no international conventions regarding the requirements of the anchor and anchor windlass as hardware. IACS have decided a common requirement regarding the anchor and windlass among its members. For example, while the class NK (Nippon Kaiji Kyokai) is a recognized organization as an IACS member in Japan, the Japanese Government (Maritime Bureau, Ministry of Land, Infrastructure, Transportation and Tourism) is also carrying out the ship's inspection and issues all the documents which are relevant to the regulations. For this reason, the legislation on the requirements regarding the anchor and anchor windlass are well established in Japan.

Furthermore, the anchor windlass is the one of the compulsory equipment items on all vessels inspected by classification societies or the government as well as the anchors and anchor chains. There are requirements on the anchor and anchor windlass in the IACS requirements and recommendations (IACS, 2005) which have been agreed by the classification society members (see Annex II).

The anchor and anchor chain are required in the above requirement in all classification societies. However, the anchor is equipped in order to hold under a wind speed of 25m/sec as an example, yet the wave drifting power is not taken into consideration in this requirement. As mentioned in Chapter 2, most accidents are caused not only by the wind and tidal stream but also by the swell.

When it comes to the performance requirement of the anchor windlass, it is just a recommendation of IACS. This recommendation is laid down in IACS recommendation No.10 (see Annex III). According to this recommendation, it mentions that the performance of anchor windlasses is taken into account at just under a wind speed of 14 m/sec, a water current of 3 knots and an anchorage depth of 100m. This means the anchor windlass might not be able to heave the anchor without assistance from, for example, the main engine if the wind blows at 20m/sec. In addition, if maintenance is carried out improperly, performance would obviously decline.

3.3 Training requirements for anchor windlass operations in the STCW convention and IMO Model courses

Seafarer's competence would be obviously essential in order to prevent accidents or incidents along with the technical requirements. The STCW convention requires a training standard for seafarers at the international level. In addition to the convention, the STCW Code Part A is mandatory and Code Part B is a recommendation. The STCW convention was reviewed comprehensively in 1995 and this revision is a current version although a smaller revision has since taken place. Especially, the competencies at both levels (Operational level and Management level) are laid down in the STCW Code A-II and A-III for deck officers and engineering officers respectively.

IMO Model courses are the recommendation which guides the recommended curriculum for MET institutions and some relevant places to implement the IMO conventions. Model courses 7.01, 7.02, 7.03 and 7.04 mention the curricula for the deck officer and engineering officer under Chapters II & III of the STCW.

3.3.1 Competence requirements of the STCW

In chapter II of the STCW and its Code, the training requirements for deck officers including the master are laid down. The deck department is in charge of the anchor handling they should have the competency for anchor handling.

II/1 of the STCW requires the competencies for deck officers at the operational level and II/2 requires the competencies for masters and chief mates at the management level. However, there are some fundamental requirements for their competencies on anchor handling in the Code A as mandatory as shown in the Table 1. Here, the handling of anchor windlass and knowledge of the deck machinery are not mentioned.

Table 1 Competence Table extracted from Table A-II/2 of the STCW 78/95

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Manoeuvre and handle a ship in all conditions	Manoeuvring and handling a ship in all conditions, including: ***(omitted)*** 9. **choice of anchorage; anchoring with one or two anchors in limited anchorages and factors involved in determining the length of anchor cable to be used** 10. **dragging anchor; clearing fouled anchors** ***(omitted)***	Examination and assessment of evidence obtained from one or more of the following: 1. approved in-service experience 2. approved simulator training, where appropriate 3. approved manned scale ship model, where appropriate	All decisions concerning berthing and anchoring are based on a proper assessment of the ship's manoeuvring and engine characteristics and the forces to be expected while berthed alongside or lying at anchor. While under way, a full assessment is made of possible effects of shallow and restricted waters, ice, banks, tidal conditions, passing ships and own ship's bow and stern wave so the ship can be safely manoeuvred under various conditions of loading and weather.

Next, in Chapter III of the STCW, the training requirements for the engineering officer are laid down. Generally, the engine department is in charge of the maintenance of the deck machinery. However, they do not use the deck machinery in their routine duties. If there is a problem with the anchor windlass, the deck officer would ask the engineering officer to make an inspection. In III/2 of the STCW at the management level, there is a requirement for the engineering officers to have competencies on the operation and maintenance of deck machinery (see Table 2).

Table 2 Competence Table extracted from Table A-III/2 of the STCW 78/95

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Operate, monitor and evaluate engine performance and capacity	*Practical Knowledge* Operation and maintenance of : 1. marine diesel engines 2. marine steam propulsion plant 3. marine gas turbines ***(omitted)***	Examination and assessment of evidence obtained from one or more of the following: 1. approved in-service experience 2. approved training ship experience 3. approved simulator training, where appropriate	The methods of measuring the load capacity of the engines are in accordance with technical specifications Performance is checked against bridge orders Performance levels are in accordance with technical specifications
Maintain safety of engine equipment, systems and services	**Operation and maintenance of cargo handling equipment and deck machinery**	Examination and assessment of evidence obtained from one or more of the following: 1. approved in-service experience 2. approved training ship experience	Arrangements for ensuring the safe and efficient operation and condition of the machinery installation are suitable for all modes of operation

Although the engine department is not the operator of the deck machinery, those competencies are required in chapter III of the STCW. Generally speaking, on most vessels, the engine department would not be in charge of the operation of the deck machineries. For example, the SMS manual of the sea training institute in Japan which operates the five training ships lays down the roles of each department, which mentions that the deck department is in charge of the operation of the deck machineries and the engine department is in charge of their maintenance (NIST, 2006).

3.3.2 Curricula in IMO Model Courses

In the IMO Model Course 7.01 (Master and Chief Mate) which follows the requirement in II/2 of the STCW, the syllabus for competence of a ship's auxiliary machinery at the management level is mentioned, yet there is little content on the deck machinery and hydraulic systems. However, it does not mention training items on anchor handling (IMO, 1999a).

In addition, it is recommended that the allocated hour for anchor handling and anchor procedure is only 6 hours (1.9.1.8 anchoring) and a part of 36 hours (1.10.2 Ship's auxiliary machinery) in Model Course 7.01 to fulfill the requirements (ibid.). Compared with the total allocated hours (379 hours) in Navigation at management level, it would be so small that seafarers can not obtain their competencies well. If this curriculum is taking place on the training ship or actual seagoing service, some merchant ships are not able to have enough time for anchoring depending upon the type of vessel. For example, it is assumed that cadets or seafarers are engaged and trained on a ferry which sails between the ports back and forth. In this case, they may not experience anchoring during this service.

In IMO Model Course 7.02 (Chief Engineer Officer and Second Engineer Officer) which follows the requirement in III/2 of the STCW, the syllabus of competence on operation and maintenance of cargo handling equipment and deck machinery at the management level is mentioned, and the items on the explanation of the windlass characteristics are required responding to competence table III/2 of the STCW Code (IMO, 1999b).

In IMO Model Course 7.03 (Officer in charge of a navigational watch) which follows the requirement in II/1 of the STCW and 7.04 (Engineer officer in charge of a watch) which follows the requirement in III/1 of the STCW, no items are required regarding the windlass operation (IMO, 1999c) (IMO, 1999d).

3.3.3 Future revision of the STCW

In June 2010, the diplomatic conference to adapt amendments to the STCW 1978 and STCW code was convened in Manila, Republic of the Philippines. The comprehensive review of the STCW convention and the STCW code had been taking place through the several annual STW sub-committee meetings and two intersessional meetings of the STW working group at the IMO headquarters in London. In Manila, the new amendment of the STCW convention was adopted by member states. This convention will enter into force on 1st January 2012.

In this comprehensive review of the STCW convention, the competence tables of the code A-III/2 (Chief engineer officer and second engineer officer) are completely revised to introduce mainly the concept of the Engine Room Resource Management (see Table 3) (IMO, 2010). The words look different compared with the previous competence table but the required competency on windlass operation is nothing different.

On the other hand, the requirement of anchor handling and windlass operation for the deck department (Chapter II of the STCW convention) is still the same as previously.

In addition to this amendment, it is said that the revision work of the IMO Model Course is being done to keep up-to-date.

Table 3 Competence Table extracted from Table A-III/2 of the revised STCW in 2010

<table>
<tr><th>Column 1</th><th>Column 2</th><th>Column 3</th><th>Column 4</th></tr>
<tr><th>Competence</th><th>Knowledge, understanding and proficiency</th><th>Methods for demonstrating competence</th><th>Criteria for evaluating competence</th></tr>
<tr>
<td>Plan and schedule operations</td>
<td rowspan="2">Theoretical knowledge

Thermodynamics and heat transmission

Mechanics and hydromechanics

(omitted)

Practical knowledge

Start up and shut down main propulsion and auxiliary machinery, including associated systems

Operating limits of propulsion plant

The efficient operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery

Functions and mechanism of automatic control for main engine

Functions and mechanism of automatic control for auxiliary machinery including but not limited to:

1. generator distribution systems
2. steam boilers
3. oil purifier
4. refrigeration system
5. pumping and piping systems
6. steering gear system
7. cargo-handling equipment and deck machinery</td>
<td>Examination and assessment of evidence obtained from one or more of the following:
1. approved in-service experience
2. approved training ship experience
3. approved simulator training, where appropriate
4. approved laboratory equipment training</td>
<td>The planning and preparation of operations is suited to the design parameters of the power installation and to the requirements of the voyage</td>
</tr>
<tr>
<td>Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery</td>
<td>Examination and assessment of evidence obtained from one or more of the following:
1. approved in-service experience
2. approved training ship experience
3. approved simulator training, where appropriate
4. approved laboratory equipment training</td>
<td>The methods of preparing for the start-up and of making available fuels, lubricants, cooling water and air are the most appropriate

Checks of pressures, temperatures and revolutions during the start-up and warmup period are in accordance with technical specifications and agreed work plans

Surveillance of main propulsion plant and auxiliary systems is sufficient to maintain safe operating conditions

The methods of preparing the shutdown and of supervising the cooling down of the engine are the most appropriate

The methods of measuring the load capacity of the engines are in accordance with technical specifications

Performance is checked against bridge orders

Performance levels are in accordance with technical specifications</td>
</tr>
</table>

When those requirements which are mentioned above were established, it would be thought it is a sufficient standard for anchor handling competence. However, the global climate has changed obviously as mentioned in Chapter 2. Under the current situation, accidents regarding anchor handling may continue to happen. Nowadays, this issue becomes inevitable.

3.4 Summary

In this chapter, the characteristics of anchor windlass, the technical requirements of anchor windlass and training requirement in the STCW convention have been considered. The existing requirements and recommendations of IACS do not have a legal binding force. In addition, the STCW requirement and the recommendation in the IMO Model Courses do not seem to be enough to prevent anchoring operation accidents occurring. What requirements should be necessary on this matter? In the next chapter, the counter measures will be analyzed.

Chapter 4. Application of the analytical method to the accident cases

4.1 Classification by using 5-M of accidents factors

The accidents mentioned in Chapter 2 are classified by the 5-M of accident factors. The 5-M stands for Man, Machine, Medium (Environment), Management and Mission. This classification has been developed within the aviation branch. In the beginning, T. P. Wright of Cornell University introduced the 3-M - man, machine, environment (medium) triad during the late 1940's. The forth M, Management was introduced in 1965 at the University of Southern California. The Mission factor was introduced in 1976 by E. A. Jerome (Wells, 2004). These 5-Ms are interrelated with each other as shown in Fig. 9.

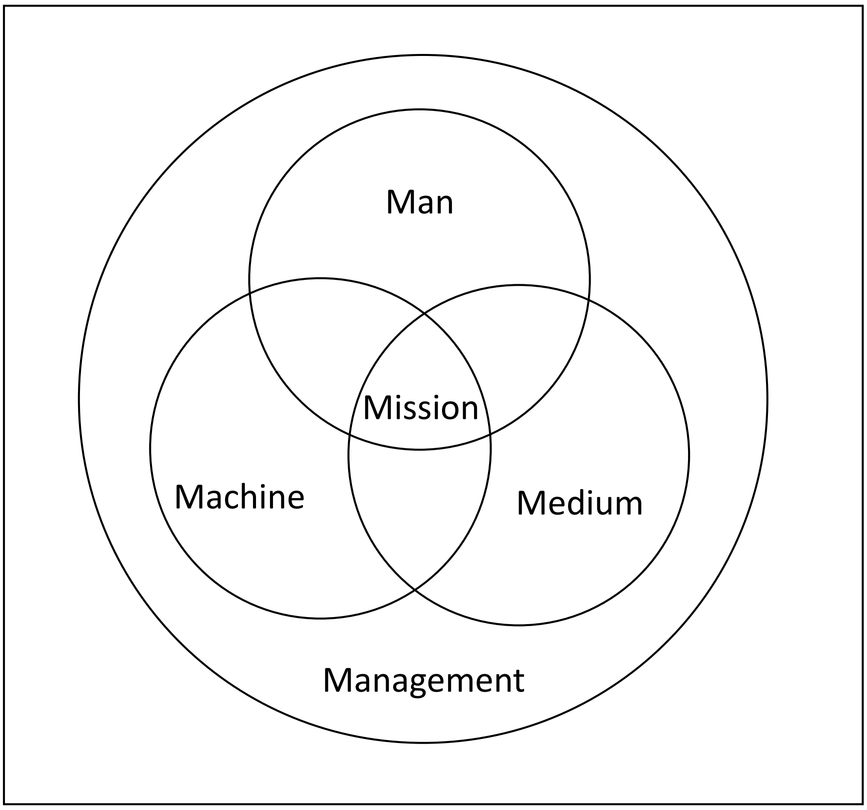


Fig. 9 Diagram of the 5-M of accident factors

The 5-M is able to be applied in the other fields such as marine accidents cases. Although 5-M is still a broad classification, its breakdown was applied in this analysis. As these accident factors are widely used in accident investigations, the accident investigation of Kaiwo Maru done by NIST in 2005 also applied this classification method (NIST, 2005). The breakdown of the category which is classified in the analysis is shown in Table 4.

Table 4 Classification of accidents factors based on 5-M

Main category	Assortment Number	Sub-category
Category 1: Man	1.1	Misjudgment and mishandling
	1.2	Bad relationship among crew (teamwork)
	1.3	Miscommunication
	1.4	Improper command and orders
Category 2: Machine	2.1	Defect of design
	2.2	Lack of maintenance
	2.3	Lack of ergonomics consideration
Category 3: Medium (Environment)	3.1	Improper work & working environment
	3.2	Defect on Man-machine interface
	3.3	Severe weather conditions
	3.4	Inadequate information from outside
Category 4: Management	4.1	Lack of safety awareness of management personnel
	4.2	Lack of leadership
	4.3	Ill-preparedness of the governing organization
	4.4	Ill-preparedness of manuals
	4.5	Lack of education & training
Category 5: Mission	5.1	Extreme schedule
	5.2	Loyalty for duty
	5.3	Face (honor)

These elements (sub-category) were applied to all the accident cases mentioned in Chapter 2 and checked one-by-one as to whether each element corresponded or not. This work has been done by the group. The members have approximately 7 to 9 years of sea-going experience with a master mariner certificate laid down in Chapter II/2 of the STCW convention.

4.2 Analysis by using the Quantification method type III

Quantification is that the qualitative data is converted to quantitative data. Obviously, even if the data is descriptive, such as free opinions in the questionnaire, it may be difficult to analyze the qualitative data.

The Quantification method type III is the one of multivariate analyses. This method is the same as the factor analysis or the principle component analysis based on the category data, which is qualitative and does not have external criteria (Ohsumi, 2006). For example, if the data is like “sweet or salty” or “hot or cold” (there is external criteria), this method is not able to be applied. This Quantification method type III has almost the same characteristics as Correspondence analysis.

While there are six types of quantification methods, four of them (types I, II, III and IV) have been commonly used. The Quantification method was established by Japanese professor, Dr. Chikio Hayashi before Correspondence analysis was invented by Benzécri of France (Ohsumi, 2004).

In this research, the method was applied to the classification of the accident data by using the element mentioned in Table 4.

4.2.1 Concept of Quantification method type III

It is necessary to explain the concept of Quantification method type III by using a simple example in order to apply this method in this research. The concept is the following (Hasegawa, 2004).

Table 5 Sample Matrix of five responses

	Y_1	Y_2	Y_3
X_1	0	1	0
X_2	1	0	1
X_3	0	1	1

The data are given by the responses using 1 or 0 (see Table 5). The point of "1" means the responses. There are five responses. In this case, X_i is called *Sample* and Y_i is called *Category*. The five responses are (X_1, Y_2), (X_2, Y_1), (X_2, Y_3), (X_3, Y_2) and (X_3, Y_3).

In the beginning, the order of X_i and Y_i need to be changed so that the correlation between X_i and Y_i can be maximal. The correlation can be calculated as the following formula.

$$\mathrm{r\ (correlation)} = \frac{\sum(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum(X_i - \overline{X})^2 \sum(Y_i - \overline{Y})^2}}$$

$$\overline{X}, \overline{Y} : \mathrm{mean}$$

As the values of Xi and Yi are a relative number, there is no problem to define that the means of X and Y are 0 and the variances are 1 as follows:

$$\overline{X} = \overline{Y} = 0$$

$$v_X{}^2 = \sum(X_i - \overline{X})^2 = 1$$

$$v_Y{}^2 = \sum(Y_i - \overline{Y})^2 = 1$$

$$v^2 : \mathrm{variance}$$

According to the above definition, as the total number of data is five, the following formula is worked out.

$$r = \frac{X_1Y_2 + X_2Y_1 + X_2Y_3 + X_3Y_2 + X_3Y_3}{5}$$

Next, the correlation is calculated so as to be the maximum under the above condition.

$$X_1 = 1.414,\ \ X_2 = -1.144,\ \ X_3 = 0.437 \quad [\textit{Sample score}]$$
$$Y_1 = -1.414,\ \ Y_2 = 1.144,\ \ Y_3 = -0.437 \quad [\textit{Category score}]$$

When the condition is like X and Y as shown above, the correlation is a maximum as follows;

$$r = 0.809$$

X and Y are changed in ascending order as follows;

$$X_2(-1.144) < X_3(0.437) < X_1(1.414)$$
$$Y_1(-1.414) < Y_3(-0.437) < Y_2(1.144)$$

The following matrix as a permutation is obtained according to the calculation (Table 6).

Table 6 Permutation matrix

	Y_1	Y_3	Y_2
X_2	1	1	0
X_3	0	1	1
X_1	0	0	1

However, when applying the quantification method type III, the two-dimensional scatter diagram is necessary to interpret the result. This means it is essential to calculate one more score of X and Y.

In this case, the other scores are defined as (X'_1, Y'_2), (X'_2, Y'_1), (X'_2, Y'_3), (X'_3,

Y'_2) and (X'_3, Y'_3). Here, X' and Y' must be uncorrelated with the first X and Y. The calculation is the same process.

4.2.2 Application of the Quantification method type III to anchor handling accidents

As far as the application of the quantification method type III is concerned, software was used in this analysis. That is the add-in software of Microsoft Excel, “Excel Statistics 2006” published by Social Survey Research Information Co., Ltd, Japan (SSRI). The quantification method type III was applied by using the accident cases as *Sample* and the classification shown in Table 4 as *Category*.

Table 7　Counting of responses of each Category in 47 accident cases

Category		Counting of Responding
1. Man	1.1 Misjudgment & Mishandling	41
	1.2 Bad relationship between crew (teamwork)	9
	1.3 Miscommunication	7
	1.4 Improper command and orders	23
2. Machine	2.1 Defect of design	4
	2.2 Lack of maintenance	8
3. Medium (Environment)	3.1 Improper work & working environment	14
	3.3 Severe weather conditions	39
	3.4 Inadequate information from outside	6
4. Management	4.1 Lack of safety awareness of management personnel	38
	4.2 Lack of leadership	3
	4.3 ill-preparedness of the governing organization	10
	4.4 Ill-preparedness of manuals	2
	4.5 Lack of education & training	32
5. Mission	5.2 Loyalty for duty	1

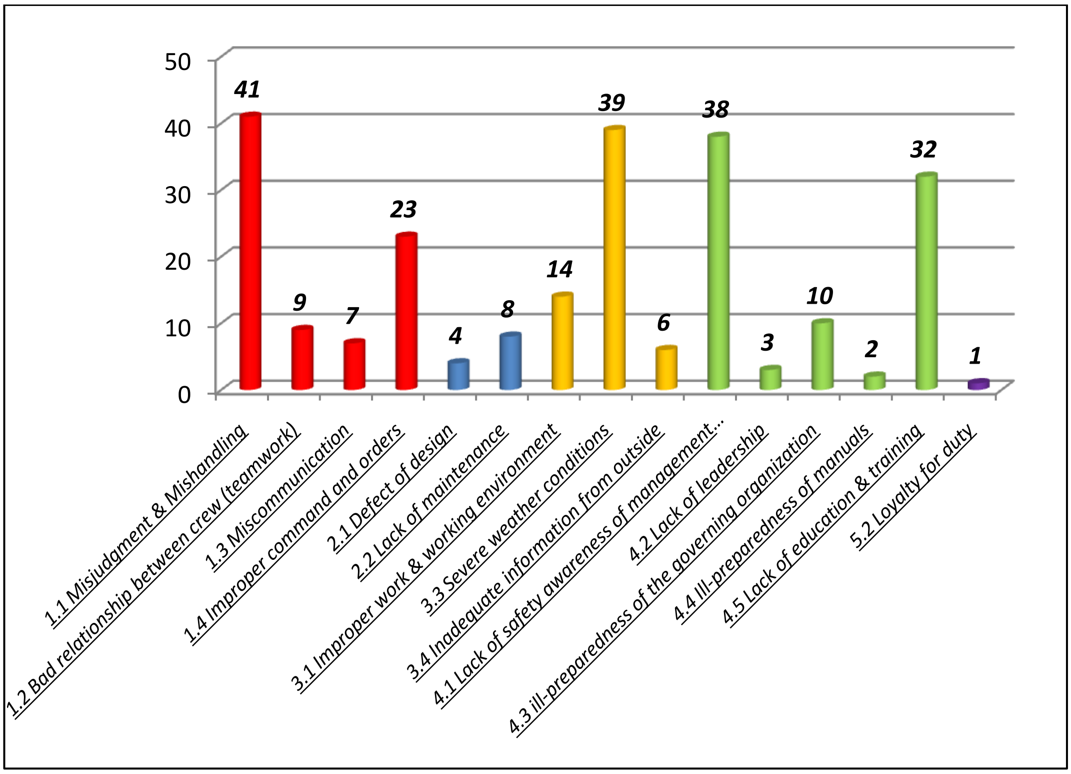


Fig. 10　Counting of responses of each Category in 47 accident cases

Table 8 Characteristic Number, Contribution Rate and Correlation Coefficient

	Characteristic Number	Contribution Rate	Accumulate Contribution Rate	Correlation Coefficient
Tendency 1	0.3063	17.86%	17.86%	0.5535
Tendency 2	0.2196	12.81%	30.67%	0.4686

According to Table 8, although the correlation coefficient is not high, this would be the reason that all the accident cases such as grounding, collision and losing the anchor have been analyzed. If only similar cases are analyzed, this correlation coefficient would be higher.

Fig. 11 and Fig. 12 show Category plot and Sample plot respectively. Table 9 and Table 10 show the raw data of Category plot and Sample plot respectively. As a characteristic of the quantification method type III, there is the same tendency on each axis of both Category plot and Sample plot (Hasegawa, 2004).

According to Fig. 11 and Fig. 12, Tendency 1 would mean the degree of technical element because '2.2 Lack of maintenance' and '2.1 Defect of design' are plotted at a high score and '4.2 Lack of leadership' is plotted at a low score. In Fig.12 (Sample plot), the accidents on the mechanical failure are plotted at a high score (ix, xxxv, xlvi)

On the other hand, regarding Tendency 2 in Category plot, only '4.4 Ill-preparedness of manuals' is plotted at a high score and only '4.2 Lack of leadership' is plotted at a low score. Although it is difficult to determine the tendency, Tendency 2 would mean the degree of management factor.

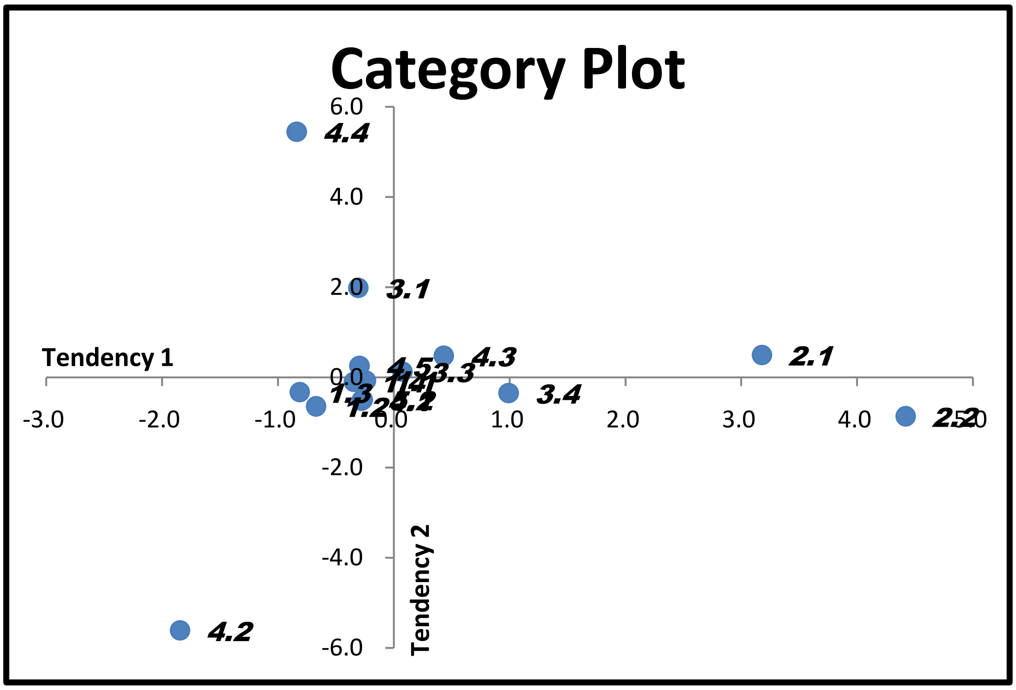


Fig. 11 Category plot from Quantification method type III

Table 9 Category score from Quantification method type III

Category	Tendency 1	Tendency 2
1.1 Misjudgment & Mishandling	-0.2396	-0.0678
1.2 Bad relationship between crew (teamwork)	-0.6701	-0.6400
1.3 Miscommunication	-0.8123	-0.3268
1.4 Improper command and orders	-0.3435	-0.0966
2.1 Defect of design	3.1783	0.5004
2.2 Lack of maintenance	4.4180	-0.8614
3.1 Improper work & working environment	-0.3053	1.9888
3.3 Severe weather conditions	0.0750	0.1303
3.4 Inadequate information from outside	0.9912	-0.3446
4.1 Lack of safety awareness of management personnel	-0.2780	-0.5121
4.2 Lack of leadership	-1.8442	-5.6111
4.3 Ill-preparedness of the governing organization	0.4318	0.4804
4.4 Ill-preparedness of manuals	-0.8380	5.4507
4.5 Lack of education & training	-0.2965	0.2552
5.2 Loyalty for duty	-0.2686	-0.4937

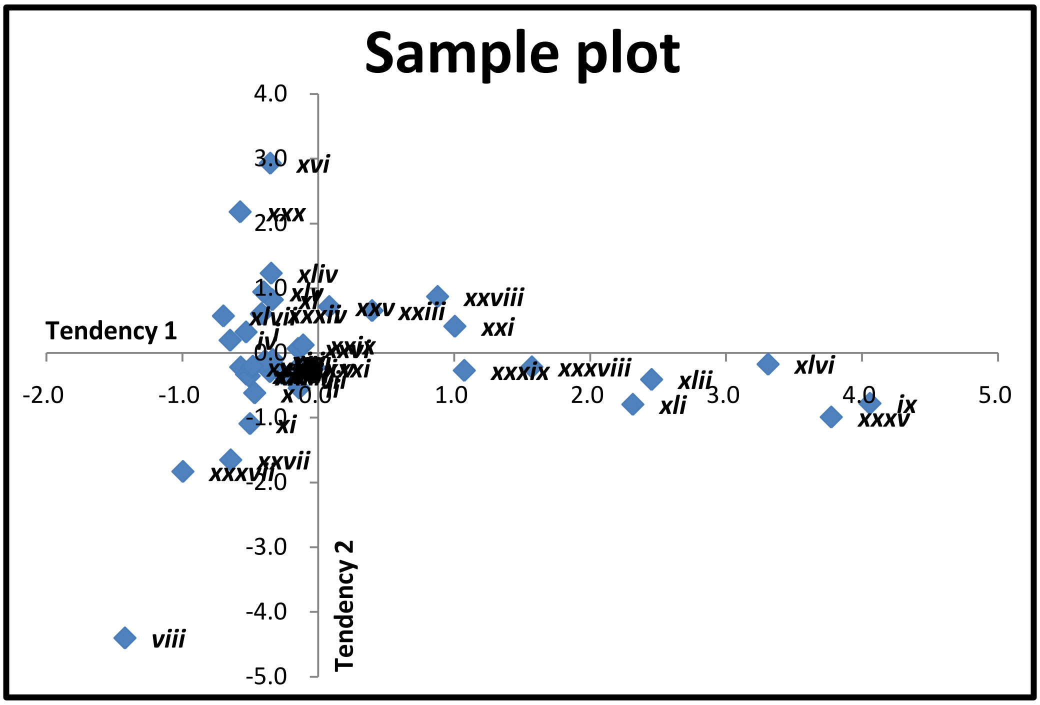


Fig. 12 Sample plot from Quantification method type III

Table 10 Sample score from Quantification method type III

Sample No.	Tendency 1	Tendency 2	Sample No.	Tendency 1	Tendency 2
i	-0.53122	0.322439	xxv	0.080806	0.71504
ii	-0.14005	-0.54443	xxvi	-0.14872	0.066629
iii	-0.26659	-0.31985	xxvii	-0.64398	-1.6528
iv	-0.64827	0.194974	xxviii	0.878178	0.870433
v	-0.02753	-0.22608	xxix	-0.11105	0.121997
vi	-0.26659	-0.31985	xxx	-0.57455	2.179105
vii	-0.18344	-0.4074	xxxi	-0.14865	-0.23135
viii	-1.42239	-4.40367	xxxii	-0.41796	0.603777
ix	4.05881	-0.78002	xxxiii	-0.50924	-0.35613
x	-0.46762	-0.61879	xxxiv	-0.41796	0.603777
xi	-0.50235	-1.09282	xxxv	3.774633	-0.99141
xii	-0.35511	-0.29143	xxxvi	-0.4903	-0.23103
xiii	-0.50924	-0.35613	xxxvii	-0.9958	-1.83219
xiv	-0.39122	-0.12425	xxxviii	1.571959	-0.21666
xv	-0.33386	-0.10377	xxxix	1.074642	-0.27119
xvi	-0.35311	2.929628	xl	-0.33786	0.821082
xvii	-0.39122	-0.12425	xli	2.314721	-0.79546
xviii	-0.57062	-0.21975	xlii	2.452606	-0.41084
xix	-0.39122	-0.12425	xliii	-0.48179	-0.20738
xx	-0.39122	-0.12425	xliv	-0.34619	1.230411
xxi	1.005226	0.410839	xlv	-0.40109	0.943097
xxii	-0.39122	-0.12425	xlvi	3.309825	-0.17459
xxiii	0.395974	0.653054	xlvii	-0.69804	0.570705
xxiv	-0.52781	-0.33114			

4.2.3 Implication of the result of the analysis

According to Fig. 11 and Fig. 12, most of the factors are plotted closely to each other at the center. Here, the center means the score is 0 (zero). The items are plotted near to each other have a strong correlation. Especially in Fig. 11, most of the factors plotted at the center would have a strong correlation.

Looking at the plots at the center, the following categories are plotted closely to each other.

1.1 Misjudgment & Mishandling
1.4 Improper command and orders
3.3 Severe weather conditions
4.1 Lack of safety awareness of management personnel
4.3 Ill-preparedness of the governing organization
4.5 Lack of education & training
5.2 Loyalty for duty

Among the above factors, only '5.2 Loyalty for duty' counted as one in the accident cases (accident of xxxi. Kaiwo Maru). In addition, the accident reports which were collected in this research do not mention 'Loyalty for duty' although this element might be included. Beside '5.2 Loyalty for duty', these factors seem to influence anchor handling accidents.

In respect of '4.1 Lack of safety awareness of management personnel' and '4.3 Ill-preparedness of governing organization', these factors are both management issues. As the ISM Code entered into force partially in 1997, the safety management system can solve these kinds of accident factors by using a Plan-Do-Check-Act (PDCA) cycle in the future.

For that reason, the following four factors are focused on.

1.1 Misjudgment & Mishandling
1.4 Improper command and orders
3.3 Severe weather conditions

4.5 Lack of education & training

What kind of counter measures do we need? According to the above four factors, all of them were counted more than 23 times in total in the 47 cases. These are four of the top five factors as well (see Fig. 10). If it is assumed that '1.1 Misjudgment and mishandling' and '1.4 Improper command and orders' are derived from the '4.5 Lack of education & training', it would be essential that education and training under severe weather should be emphasized. That is to say, lack of education and training under severe weather would largely influence anchor handling accidents.

What kind of contents for education and training should thus be included? The next chapter discusses and suggests the model syllabus for a comprehensive anchor handling course.

Chapter 5. Suggestions for anchor handling education and training

In Chapter 4, the factors of anchor handling accidents were defined. For MET institutions, it is necessary to consider the availability of education and training on comprehensive anchor handling especially for the deck department as an operator. As mentioned in Chapter 3, there have been no regulatory frameworks on the performance of anchor windlass at the international level such as the SOLAS convention, although the requirements for the anchor and its chain are laid down in the IACS requirements. It is important that proficiency in windlass handling is obtained for personnel at the management level such as master and chief mate because they are practically commanding either on the bridge or on the mooring deck. This education and training would need to supplement the lack of a requirement on anchor windlass as hardware. Especially, the competency under severe weather is essential regarding this issue.

The education and training of the deck department is focused on here because none of the engineering officers have been involved in the accident cases mentioned in Chapter 2. In this chapter, the syllabus of anchor handling at the management level of the deck department is suggested as an amendment to the STCW convention. In addition, the availability of anchor handling education and training is also suggested. MET is divided into two parts; one is on-shore and the other is on-board. In fact, only practical training is required on-board.

5.1 Syllabus for anchor handling education and training

The education and training of anchor handling are essential at the management level of the deck department. Besides the aim, objectives and learning outcomes, the syllabus on anchor handling at the management level of deck department should cover the following items including both the theoretical part and practical part:

1. Legal framework on anchor, chain and anchor windlass;
2. Basic principles of anchor windlass;
3. Procedures for letting go and weighing anchor;
4. Detection of dragging anchor and the appropriate action when dragging;
5. Handling of anchors at extraordinary situations;
6. Limit performance of anchor windlass and anchor holding power;
7. Maintenance issues coping with engine department;
8. Team management between bridge and forecastle for an emergency situation on anchor handling at a risk of danger.

Taking into account the above items, a syllabus is suggested in the following tables. The suggested syllabus should be tacked on to the existing syllabus in the IMO Model Course 7.01 Master and Chief Mate – Competence 1.9 – 1.8 Anchoring (allocated hour: 6 hours).

Table 11 Suggested Syllabus on anchoring and windlass operation

Knowledge, understanding and proficiency
1 Legal framework on anchor, chain and anchor windlass **Required performance** **Understand the essential legal framework on anchor, anchor cable and anchor windlass** 1.1 Understand IACS requirement UR-A (concerning MOORING, ANCHORING and TOWING) 1.2 Understand IACS recommendation part 10 1.3 Understand National legislation, requirement related to anchor and windlass 1.4 Explain a scope on the annual ship inspection regarding anchor, anchor cable and windlass
2 Basic principles of anchor windlass **Required performance** **Explain the principles of anchor windlass and basic operations of windlass handling** 2.1 Explain detailed mechanism and different types of system (Electric and Hydraulic) 2.2 Describe function of the operational devices (Clutch, Brake, Stopper and Control Lever) 2.3 Define function of safety devices which release the overload
3 Procedures for anchoring and weighing anchor **Required performance** **Demonstrate the procedures of ship handling for anchoring and weighing anchor** 3.1 *Explain how to choose an anchorage and list the factors which influence the choice** 3.2 *State that an anchoring plan should be prepared in advance, showing direction and speed of approach and the dropping position(s), with checking bearings** 3.3 *Describe the preparation of anchors, including walking the anchor back for anchoring in deep water** 3.4 *Explain how to judge that a ship is stopped ready for letting go** 3.5 *Explain that positions should be obtained on letting go and again when brought up** 3.6 *Describe the use of anchor buoys** 3.7 *List the factors to consider in determining the length of anchor cable to be used as:** ● *the nature of the bottom** ● *the strength of current or wind** ● the height of wave (swell) ● *the exposure of the anchorage to bad weather** ● *the amount of room to swing** ● *the expected length of stay at anchor**
4 Detection of dragging anchor and the appropriate action when dragging **Required performance** **Demonstrate how to detect dragging anchor; Describe the appropriate actions after detecting dragging** 4.1 *Define dragging and explain how to detect it** 4.2 *Describe the actions to be taken when the anchor starts to drag** 4.3 Demonstrate the appropriate engine use so as to prevent the dragging anchor

* Listed in the IMO Model course 7.01 (Italics)

5 Handling of anchors at extraordinary situations

Required performance
Demonstrate the procedure at extraordinary situations

5.1 *Explain how excessive yawing may break the anchor out of its holding and describe measures to control yaw** (how to check swing of a ship)
5.2 *Describe how to bring a ship to an open moor**
5.3 *Explain what is meant by 'foul hawse' and how it occurs**
5.4 *Describe how to clear a foul hawse**
5.5 *Describe how to clear a fouled anchor**
5.6 *Describe how to buoy and slip an anchor**

6 Limit performance of anchor windlass and anchor holding power

Required performance
Understand limit performance of standard anchor windlass and anchor holding power against external force

6.1 Understand a limit performance of standard anchor windlass required in IACS UR-A and recommendation against external force (wind, current and wave) on different types of ships (Case study)
6.2 Understand an anchor holding power against external force on different types of ships (Case study)

7 Maintenance of anchor and anchor windlass

Required performance
Understand an importance of maintenance

7.1 Understand an importance of marking each shackles
7.2 Understand needs of periodical maintenance of anchor windlass (Brake liner, Safety devices, greasing)
7.3 Explain how to maintain proper performance of anchor windlass

8 Team management between bridge and forecastle for the emergency situation on anchor handling at a risk of danger

Required performance
Demonstrate an optimal performance between bridge and forecastle

8.1 Demonstrate an optimal performance as a master on bridge at a risk of danger
8.2 Demonstrate an optimal performance as a chief mate on forecastle at a risk of danger

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* Listed in the IMO Model course 7.01 (Italics)

5.2 On-board training and its limitation

The cadets who are candidates for watch officer of the deck department at operational level, as regulated in the chapter II/1 of the STCW convention, must have at least 12 months experience at sea. They are trained by using a training record book (TRB) and are assessed through it. A maritime administration can control their on-board training by using the TRB. However, the suggested training in this paper is not for the operational level. It would be difficult for a maritime administration to unify the on-board training without any criteria like the TRB.

To be a Master, at least three years (36 months) experience on board a vessel (of more than 3,000 gross tonnage) is required under the STCW convention, although there is an exceptional condition. Then there is one question: can a liner ferry have the anchoring operation? Obviously, the crew of a liner ferry would seldom have experience of anchoring under a regular operation. In addition, another problem is how can they train anchor handling when the ship is underway? How many times per year can a crew have experience of anchor handling? In this paper, the real situation on-board ship was not researched concerning these issues, but there would be a lot of constraints to on-board training. For this reason on-board training would not be suitable for extraordinary situation training.

5.3 Education and training on shore

The education part and the training part should be considered separately here. The main part of the education is a classroom lecture although there are several styles of class such as seminars and buzz groups (Brown & Atkins, 1988). No matter how the style of a class is, teachers can convey their words in a class room. The essential aspects are qualified instructors, as laid down in regulation I/6 of the STCW convention, and effective study materials such as videos and pictures.

On the other hand, in respect of the practical training on shore, so far there has been no measure to implement the suggested syllabus. Especially, the place and the way (where and how) to carry out the anchor handling training under extraordinary situations could be an issue to be solved. Fortunately, as computer technology progresses, the use of a simulator may be the solution.

In fact, an "Anchor handling simulator" has been developed and been used, yet it is used for the personnel of an anchor handling vessel in the offshore industry (Kongsberg). For this reason, a new simulator system which can reproduce all kinds of situations at anchor should be developed for implementing the suggested syllabus. This new system can be built up from an ordinary ship handling simulator. The concept of the system is shown in Fig. 13.

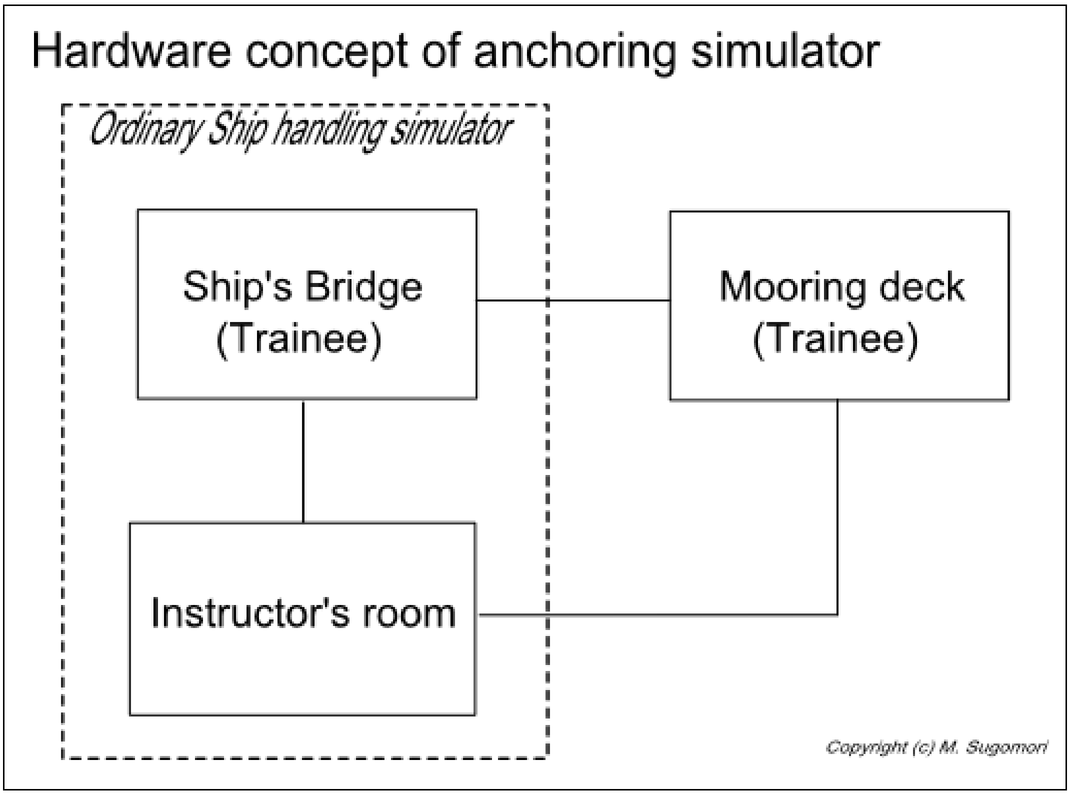

Fig. 13 Hardware concept of anchoring simulator

In fact, the operation of the windlass is taking place at the mooring deck (forecastle deck). It must have a function of the operation there. However, the most important requirement is the control models in the computer. If the control models do not work like a real machine, the performance of the simulator would be useless. Furthermore, beside the performance of the simulator, the scenarios should cover the following items:

- Ship handling training when anchoring (proper choice of anchorage);
- Anchor watch training when the wind becomes severe;
- Training for preventing the dragging of the anchor;
- Behavioral training after dragging the anchor;
- Heave-up-anchor training under severe weather in different conditions (wind, current and wave) to get to know the limit performance of the windlass;
- Open mooring training;
- Slipping anchor training;
- Training for clearing a fouled hawse.

5.4 The other possibilities for anchor handling training

There are opportunities for having training on-board. These include emergency training and drills which are laid down in Regulation 19 of Chapter III of the SOLAS convention. The anchor handling drills and relevant on-board training can be recommended to be added to this regulation. However, compared with the other drills such as abandon ship drill and fire drill, the degree of importance would be lower because training of the emergency anchor handling is not directly related to a casualty.

On the other hand, the performance of the anchor windlass depends upon the type and size of the ship. At least the management personnel, master and chief mate should grasp the limit performance of the anchor windlass of the vessel taking into consideration the external forces before they start working on board. This can be familiarization training for the management personnel in the deck department. Every ship is recommended to have this kind of familiarization training.

To sum up, no matter how the anchor handling education and training is, the opportunity for it should be increased. The implementation of the education and training mentioned in the recommended syllabus is not a proactive approach since a large number of anchor handling accidents have already occurred.

IMO's prime duty is to act proactively in order to ensure that accidents do not happen in the first place (http://www.imo.org). At least, the same kind of accident as has happened before should not continue to occur.

Chapter 6. Conclusion

In this dissertation, anchor handling accident cases have been discussed and analyzed using the Quantification method type III. As a result, a model syllabus on anchor handling education and training has been recommended. To conclude this study, a summary of the each chapter is given here.

In Chapter 2, the anchor handling accident cases that have occurred in recent years were described. In addition, the weather impact on peak gusts was examined. The following outcomes were considered in the chapter:

1. Quite a number of anchor handling accidents have occurred, especially in recent years with the casualties being reported in stranding cases.
2. Most of the weather stations in Japan have observed a trend in the increase of the peak gust year by year.
3. According to the prediction made by JAMSTEC, it is reported that the size of the tropical cyclone will increase with ships being exposed to stronger winds than before.

In Chapter 3, the characteristics of the anchor windlasses and the regulatory bases for anchor windlasses and the requirements for anchor handling education and training were discussed. The following items were found:

1. The anchor windlass is essentially simple operation machinery, although a vital item of the ship's installation.
2. There is a need to periodically maintain the anchor windlass. There is a slight difference in the operation alert between the types of motor used for the anchor windlass.
3. There are no international technical requirements for the anchor windlass. It is only laid down in the IACS requirements and recommendations.
4. There is no training requirement in the STCW on anchor handling in an emergency situation.

In Chapter 4, the accident cases classified by 5-M of the accident factors were analyzed by using the Quantification method type III. As a result, the correlation of the accident factors and the major factors could be obtained. The following items were found in the chapter:

1. The major factors correlated strongly were identified according to the analysis. These were :
    i. Misjudgment & Mishandling
    ii. Improper command and orders
    iii. Severe weather conditions
    iv. Lack of safety awareness of management personnel
    v. Ill-preparedness of the governing organization
    vi. Lack of education & training
    vii. Loyalty for duty
2. The education and training under severe weather conditions should be taken into account.

In Chapter 5, a syllabus concerning the education and training of anchor handling was recommended. In addition, the method of the implementation of the syllabus was also discussed. The following was found:

1. Anchor handling education and training is necessary for the personnel at the management level in the deck department.
2. The syllabus suggested is based on the one existing in the IMO Model course 7.01 (See Table 11).
3. According to the discussion on the implementation of the syllabus, an anchoring simulator added to the ship handling simulator would be effective.

In Chapter 6, the conclusion highlights the main findings of the study.

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Annex I

Raw data on Peak Gusts at weather stations in Japan - ***part 1***

Year	1. Wakkanai	2. Nemuro	3. Aomori	4. Miyako	5. Sakata	6. Niigata	7. Onahama
1967	29.5	28.7	28.5	23.6	34.2	30.0	22.9
1968	30.8	24.8	25.0	22.2	34.4	27.4	24.6
1969	34.8	32.6	24.4	26.2	36.0	31.8	25.5
1970	35.0	35.6	29.5	36.7	33.2	32.8	28.0
1971	30.5	34.0	24.5	30.1	31.4	29.4	29.4
1972	38.4	34.4	27.7	31.8	32.8	31.3	26.9
1973	33.2	29.0	25.2	30.6	29.0	32.5	22.2
1974	33.6	30.0	28.8	25.7	29.4	32.5	22.5
1975	29.6	35.6	22.5	29.2	30.6	33.1	21.9
1976	31.8	35.0	27.7	30.1	29.5	30.2	20.0
1977	29.2	28.4	25.5	23.5	25.6	26.6	19.2
1978	31.7	36.0	24.5	32.9	30.1	26.3	23.0
1979	31.8	33.2	32.6	30.9	35.5	33.0	37.2
1980	32.0	34.4	25.3	30.3	29.0	29.3	30.6
1981	34.0	30.3	32.0	35.8	37.4	37.5	31.0
1982	36.6	35.2	25.8	31.8	33.2	31.8	24.9
1983	30.5	37.2	31.0	28.7	31.4	27.8	23.4
1984	39.7	26.3	22.3	20.6	28.6	29.0	28.1
1985	32.9	27.0	32.5	31.2	28.2	26.0	29.6
1986	36.1	28.0	24.1	22.2	31.3	28.1	31.1
1987	28.8	32.7	30.4	29.0	32.3	29.8	27.6
1988	32.1	37.6	22.6	24.9	29.9	29.6	31.1
1989	27.8	29.3	23.2	33.9	29.2	26.4	30.4
1990	37.0	34.8	33.4	39.1	34.2	31.0	26.6
1991	28.9	34.5	53.9	35.2	45.9	45.5	28.0
1992	31.6	34.2	26.5	25.8	35.8	35.8	26.6
1993	33.9	33.7	30.8	25.2	31.0	28.1	26.6
1994	37.9	32.8	27.6	33.4	29.8	30.4	33.5
1995	44.9	34.5	29.2	30.2	33.3	31.2	25.8
1996	29.8	33.4	25.3	28.4	29.8	28.0	33.0
1997	27.4	33.5	26.3	25.1	37.0	28.8	27.8
1998	32.5	33.2	32.7	35.0	37.0	38.8	32.4
1999	29.8	36.2	31.9	30.6	34.1	35.4	30.9
2000	30.2	33.9	31.7	30.2	32.1	35.8	24.9
2001	30.3	32.8	31.7	29.4	34.1	29.7	24.3
2002	33.2	36.0	30.7	43.5	29.8	27.6	48.1
2003	34.1	36.8	34.0	28.6	30.2	29.5	31.1
2004	34.7	39.3	36.2	35.8	40.2	37.1	26.9
2005	37.6	37.1	28.6	29.9	34.2	33.2	29.7
2006	31.9	42.2	28.5	31.1	33.5	34.7	32.7
2007	32.1	35.2	28.6	38.9	34.1	30.6	35.4
2008	25.9	33.8	27.3	24.1	27.7	25.2	26.4
2009	25.6	35.4	33.4	24.6	28.9	24.8	29.3

part 2

Year	8. Choshi	9. Izu O Shima	10. Chichishin	11. Omaezaki	12. Fushiki	13. Shiono Mi	14. Matsue
1967	32.6	35.6	–	35.5	33.5	48.5	25.6
1968	36.1	34.3	–	35.4	32.7	31.6	27.6
1969	32.3	36.0	25.2	34.8	21.8	37.2	27.0
1970	31.8	35.4	46.2	31.0	27.4	33.4	29.8
1971	49.0	37.5	29.7	30.1	26.4	32.8	34.0
1972	34.8	36.3	40.1	31.9	28.0	48.8	29.6
1973	27.3	32.0	27.0	26.3	28.4	25.1	27.8
1974	33.4	33.6	39.4	35.4	28.7	35.2	31.4
1975	35.3	33.8	35.9	27.0	30.0	30.8	24.6
1976	29.0	33.0	36.8	34.5	25.3	26.5	25.0
1977	28.4	35.0	29.7	30.5	24.3	25.8	24.1
1978	30.3	34.8	26.2	31.6	24.3	27.2	25.8
1979	39.0	45.2	24.4	43.2	31.7	38.4	32.9
1980	29.6	35.2	28.6	31.3	23.2	32.5	41.2
1981	36.4	36.4	31.3	33.4	23.1	32.5	31.7
1982	36.3	48.6	38.0	36.7	27.0	34.8	36.9
1983	30.5	35.3	58.6	32.1	25.8	36.0	29.6
1984	29.3	28.7	47.0	29.0	18.4	28.3	31.2
1985	45.8	56.7	36.4	35.1	19.2	27.1	28.1
1986	41.4	39.1	59.7	35.9	20.5	31.3	32.3
1987	32.4	37.0	40.7	28.4	30.8	32.3	32.7
1988	31.3	35.3	34.9	31.7	21.8	39.8	31.5
1989	35.4	45.0	47.0	28.6	22.4	33.1	31.7
1990	34.0	42.8	26.6	40.4	32.7	59.5	36.3
1991	30.6	35.4	37.1	34.8	37.7	31.7	56.5
1992	35.9	34.3	36.4	27.4	23.6	32.4	27.6
1993	30.4	29.6	28.1	31.7	31.2	33.4	31.2
1994	37.8	31.5	33.5	31.8	29.2	46.4	29.8
1995	46.9	43.9	32.7	33.5	23.9	30.6	30.6
1996	51.9	42.8	36.5	30.2	26.6	31.8	31.0
1997	33.5	36.4	55.1	36.1	29.2	35.7	37.1
1998	45.7	38.7	37.6	37.8	40.4	41.9	31.8
1999	35.7	33.4	29.1	35.8	25.0	35.7	37.5
2000	33.8	37.2	38.1	31.3	25.3	32.6	32.1
2001	37.6	42.9	32.5	31.1	25.3	38.2	28.8
2002	52.2	45.7	46.0	39.5	25.6	31.7	31.7
2003	35.1	33.0	55.6	30.9	25.0	42.0	32.2
2004	41.0	51.5	40.7	50.0	40.6	41.3	35.8
2005	39.6	57.0	38.0	45.7	27.4	31.1	29.9
2006	39.0	31.4	38.8	32.8	25.4	30.7	30.3
2007	40.5	41.2	40.8	37.9	27.5	32.8	35.3
2008	33.5	32.3	29.9	30.9	19.5	31.5	29.2
2009	37.5	31.7	42.9	31.4	30.3	40.4	26.9

part 3

Year	15. Hiroshima	16. Murotozak	17. Shimonos	18. Izuhara	19. Miyazaki	20. Tanegashi	21. Minamidai
1967	22.7	59.2	27.1	30.2	23.0	31.4	–
1968	23.8	52.9	32.6	47.2	25.8	47.2	34.0
1969	22.7	47.2	30.4	28.9	46.8	39.0	26.3
1970	40.0	64.3	40.4	27.9	27.3	30.4	29.5
1971	25.9	45.0	37.0	28.4	37.3	39.5	30.0
1972	25.2	49.2	36.2	33.0	25.5	32.0	35.2
1973	20.3	35.1	30.1	32.0	19.0	28.5	31.5
1974	28.0	48.9	26.2	28.8	27.5	29.3	46.3
1975	22.6	55.2	27.7	25.3	20.3	31.8	27.4
1976	31.1	35.1	36.4	30.8	28.3	30.3	56.6
1977	24.4	36.8	26.7	25.8	22.0	29.4	26.8
1978	31.4	37.0	42.2	30.8	22.9	31.9	36.9
1979	34.1	66.9	34.2	32.8	34.2	42.6	34.2
1980	30.0	36.2	29.0	39.0	31.0	42.1	42.2
1981	26.3	36.4	26.6	30.8	45.3	31.0	45.2
1982	31.6	50.3	28.6	31.0	36.7	37.2	41.2
1983	26.9	43.2	34.9	32.8	25.8	32.3	38.3
1984	28.7	33.7	28.2	26.5	21.8	33.9	31.2
1985	22.2	37.0	42.8	29.6	31.0	45.7	39.5
1986	24.9	37.2	30.6	33.3	18.6	31.6	53.5
1987	37.0	53.8	42.2	52.1	27.7	35.7	43.3
1988	22.6	40.8	31.6	32.3	24.8	31.7	50.7
1989	24.9	46.9	34.3	27.2	37.7	60.0	32.2
1990	34.0	63.5	30.6	34.1	36.0	47.6	48.4
1991	58.9	42.5	45.3	44.9	33.1	35.7	40.3
1992	26.4	52.6	35.1	28.2	38.1	42.5	40.4
1993	33.0	50.3	43.4	30.7	57.9	59.1	50.1
1994	27.7	48.8	29.4	34.3	26.0	36.1	40.6
1995	46.8	36.6	29.9	40.3	28.3	28.8	25.3
1996	27.4	44.3	39.2	28.1	36.4	44.7	47.4
1997	30.5	52.2	31.1	34.7	36.7	41.9	46.9
1998	28.7	59.6	27.7	26.9	25.5	32.8	30.0
1999	49.6	49.9	41.9	28.3	32.7	34.1	35.9
2000	28.6	42.6	31.1	33.9	26.0	32.1	61.5
2001	22.4	51.3	30.5	27.5	26.2	31.2	31.9
2002	29.9	45.7	28.6	36.8	26.7	33.2	49.5
2003	33.6	69.2	33.6	46.5	31.7	40.6	35.0
2004	60.2	60.9	39.4	48.7	44.3	45.2	52.8
2005	32.1	44.3	32.4	36.1	43.1	59.2	55.6
2006	34.9	37.7	37.0	35.4	34.2	32.5	27.9
2007	25.0	43.5	27.1	28.7	38.8	49.3	33.3
2008	23.1	30.1	21.6	22.9	23.1	33.8	24.8
2009	22.1	43.2	23.5	25.2	21.0	32.5	58.9

Annex II

IACS UR-A Requirements concerning MOORING, ANCHORING and TOWING (Partial Extract)

A1.1 Design of the anchoring equipment

A1.1.1 The anchoring equipment required herewith is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

A1.1.2 The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

A1.1.3 The anchoring equipment presently required herewith is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

A1.1.4 The Equipment Numeral (EN) formula for anchoring equipment required here under is based on an assumed current speed of 2.5 m/sec, wind speed of 25 m/sec and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

A1.1.5 It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

A1.1.6 Manufacture of anchors and anchor chain cables is to be in accordance with UR W29 and UR W18.

Annex III

IACS recommendation No.10 (2005) (Partial Extract)

1.3 Windlass design and testing

1.3.1 A windlass suitable for the size of chain cable and complying with the following criteria is to be fitted to the ship.

1.3.2 The windlass unit prime mover is to be able to supply for at least 30 minutes a continuous duty pull Zcont, corresponding to the grade of chain cables given by:

Zcont = 37.5 d2 N (4.33 d2 kgf) grade 1

42.5 d2 N (4.33 d2 kgf) grade 2

47.5 d2 N (4.84 d2 kgf) grade 3

where d = chain diameter (mm).

These figures were determined taking into account the following conditions:

(i) wind force equal to 6 on Beaufort Scale, corresponding, approximately, to 14 m/sec;

(ii) water current velocity 3 knots = 1,54 m/sec.

(iii) anchorage depth 100 m;

using ordinary stockless anchor.

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor. The temporary overload capacity or "short term pull" should not be less than 1.5 the continuous duty pull and should be provided for at least two minutes. The speed in this period can belower than nominal.

NOTE

(a) The values of Zcont include the influences of buoyancy and hawse pipe efficiency which is assumed to be 70 percent.

(b) The anchor masses are assumed to be the masses, excluding tolerances, as given in Table 2 above and in A1.4.3 Table 2. The chain masses are assumed, owing to the buoyancy, smaller than those in Table 3 and as given by P = 0,0218 d2kg per meter length.

(c) Only one anchor is assumed to be raised at a time.

1.3.3 Nominal speed of the chain cable when hoisting the anchor and cable can be a mean speed only and this speed shall be not less than 0,15 m/sec. The speed is to be measured over two shots of chain cable during the total trip; the trial should be commenced with 3 shots (82,5 m) of chain fully submerged.

1.3.4 The capacity of the windlass brake is to be sufficient for safe stopping of anchor and chain cable when paying out the chain cable. If a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part and without brake slip. If a chain stopper is fitted it should withstand a pull of 80% of the breaking load of the chain. The windlass with brakes engaged and cable lifters disengaged is to be able to withstand a pull of 45% of the breaking load of the chain without any permanent deformation of the stressed parts and without brake slip.

1.3.5 The stresses in the involved parts of the windlass, windlass frame and stopper have to be below the yield point of the material used. The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

Attention is to be paid to:

(a) stress concentrations in keyways and at other stress raisers;

(b) dynamic effects due to sudden starting or stopping of the prime mover or anchor chain;

(c) calculation methods and approximation used when deriving the design stresses.