No. 112/19, 45–59
ISSN 2657-6988 (online)
ISSN 2657-5841 (printed)
DOI: 10.26408/112.04

Submitted: 13.06.2019
Accepted: 26.11.2019
Published: 30.12.2019

ANALYSIS OF HUMAN ERRORS RELATED TO MANY MARINE ACCIDENTS OCCURRING WHILE ANCHORING AND MANOEUVRING AT AN ANCHORAGE

Grzegorz Rutkowski
Master Mariners Association, al. Jana Pawła II 3, 81-963, Gdynia Poland,
ORCID 0000-0002-7455-7069
e-mail: kptgrzegorzrutkowski@gmail.com

Abstract: The purpose and scope of this paper is to describe anchoring procedures and typical human errors that are the cause of many marine accidents related to the anchoring of vessels and their manoeuvring in anchorage areas. In this paper the author focuses on typical marine accidents recorded for very large crude carriers (VLCC). As a result of the analyses, it can be seen that in the vast majority of cases these accidents are caused by human error and are related to the violation of accepted maritime anchor practices and a failure to observe the relevant safety and security procedures. The consequences of the accidents vary from the minor (e.g. slight structural damage to the anchor winches or other marine equipment) to the serious, which result in dry dock repairs due to hull damage, loss of stability and/or loss of navigability. The described cases refer to both favourable and extremely unfavourable hydro meteorological conditions, the latter including strong winds, currents and waves within the confined anchorage area.

Keywords: human error, marine accident, anchoring, ship manoeuvring, sea transport, navigational risk.

1. INTRODUCTION

Anchoring is one of the most common and basic activities performed by the crew of a ship, and yet cases of negligence, lack of adherence to the rules and procedures, and failure to apply common sense are quite frequent. The consequences can be grave, including severe equipment damage and serious financial loss. Anchoring the vessel is a complex task requiring experience, knowledge, thinking ahead, and the ability to foresee all the possible consequences of any decision. There are numerous publications available which analyse anchoring practice in terms of specific procedures and requirements, but incidents still happen.

The European Maritime Safety Agency (EMSA, 2017], in the period from 2011 to 2016, recorded a total of 18 655 ship incidents, 16 539 casualties, 253 ships lost, 5607 people injured and 600 fatalities. Many of the accidents occurred while anchored or anchoring under difficult conditions or in deep waters when the tide/wind change. The cause is usually a failure to follow the anchoring procedures and misjudging the vessel speed over the ground while trying to control movement using the engine ahead or astern controls [Teekay internal document 2017; Health and Safety at Work 2018; NOAA 2018; UK Government Services and Information 2018].

According to the NOAA Incident News website [NOAA 2018], of the 761 navigational incidents recorded in US waters in the period from 2013 to 2017, a total of 131 (17.2%) were classified as incidents with anchoring or at the anchorage. Globally, the UK Government Services and Information website has more than 8600 records [UK Government Services and Information 2018] for the period from 2008 to 2018 related to incidents when anchoring or at the anchorage.

The three different examples described below are all typical anchorage incidents, with negligence being the main cause. The examples also include direct and root cause analyses for each scenario. Finally, the proper anchoring procedure is described, with a summary of typical human factors (errors) forming the main causes of marine accidents related to the anchoring of ships and/or their manoeuvring while at the anchorage.

Case 1: Uncontrolled dropping of the anchor. The Boson and Able-Bodied Seaman (AB) were sent forward to drop the anchor at a 66 m depth. It was a standard practice that shallow water anchoring was carried out by the Boson and AB without the presence of an officer, as the vessel anchored quite frequently (according to the company procedures [Teekay internal document 2018a], deep water anchoring was considered any depth over 40 m, in which case the presence of the Chief Officer in the anchoring party was mandatory). Both the Boson and AB were new to the vessel, and although the Master regarded this fact as a risk, clear communication was considered a sufficient countermeasure. Due to frequent anchoring, the Master did not create a job hazard analysis (JOHAN), as it was assumed that the Boson had enough experience, even though this was only his second week on the vessel. Familiarization with the vessel's anchoring practices were not discussed with either the Boson or AB. The AB came on board together with the Boson. The Chief Officer was absent. The Boson was not used to anchoring without an officer present, and his usual role was handling the brake while the AB watched the chain. The bridge team was unaware of this. Two shackles were lowered and the anchor was prepared for dropping. It was explained by UHF radio that the operation would be done in two steps, first a drop of 5–6 shackles, then slack down to 9–10 and make fast.

While dropping, a significant amount of cable passed through the hawse pipe and a thick cloud of dust appeared around the windlass. It was not possible to see how many shackles of the cable had been deployed, but the AB was sure that he had seen the red shackle, which on his previous vessel indicated 5 shackles off. Hence '5 shackles in the water' were reported to the bridge. The vessel's main engine (ME) was set for slow movement astern to lay out the chain, and the order given to slack down until low to medium tension was observed on the cable. Then '6 shackles' were reported to the bridge.

Again, the order was given to pay out the cable when low to medium tension was observed. Another length was dropped, and when the chain stopped '7 shackles' were reported to the bridge. At this point the brake was off, tension was increasing and the vessel movement astern stopped. During the entire operation neither the Boson nor the AB paid attention to how many shackles were deployed. In fact, the full length of the chain was paid out and stopped at the bitter end, resulting in minor structural damage to the chain locker and the bitter end arrangement.

In this scenario the following direct and root causes were recorded:

- Failure to follow the rules and regulations. The Master did not follow deep water anchoring procedures [Teekay internal document 2018a,b] where the Chief Officer should lead the anchoring for depths over 40 meters even if he was aware of the depth and the requirements. The Master did not prepare a job hazard analysis as it was assumed that the Boson had enough experience with anchoring practices.
- Inadequate preparation/planning. Familiarization with vessel anchoring practices were not discussed with the Boson or AB, and no pre-anchor meeting took place. With no designated roles for the two crew forward, the Boson took his usual role of handling the brake and AB the job of watching the chain – this was not communicated to the bridge.
- Inadequate supervision. The officer on the bridge did not raise any concerns regarding the lack of any chief officer presence during the operation. At no time during the operation did the Boson or AB raise any concerns regarding the number of shackles deployed.
- Inadequate leadership. Inadequate identification and evaluation of loss exposures/risks. The Master failed to ensure effective implementation of Bridge Resource Management (BRIM) and anchoring practices [Teekay internal document 2018a]. Familiarization with vessel anchoring practices were not discussed with the Boson or the AB, and no pre-anchor meeting took place.

As follow up actions, when the tension and open brake was reported to the bridge, the Master was fairly sure that all the chain was paid out and sent the Chief Officer to check. Two shackles were lifted and the anchor secured. The company procedure for anchoring, both in shallow and deep water, were reviewed with all the bridge team and deck crew. Two subsequent anchor operations were performed as per the requirements, with the Chief Officer in charge on site. Two training sessions of 2.5 hours each were conducted with all the crew to reinforce the operational leadership expectations, especially in view of stopping unsafe acts and conditions, and raising concerns when in doubt.

Case 2: Loss of anchor. The vessel anchored in a deep water anchorage. The weather forecast for the next 36 hours predicted gale to storm force winds, but at the time of anchoring the weather was good enough to maintain a safe position. The vessel was anchored with the starboard anchor, 12 shackles on deck, at a safe distance from shallow waters and other vessels. The Captain shared his concern with the Vessel Manager about being anchored in a deep water anchorage with bad weather forecast.

After discussions, the Master and Vessel Manager agreed to remain anchored, but to observe all safety measures. The next day, during the night watch, the weather began to deteriorate rapidly and the vessel started to drag her anchor. The Master was called to the bridge, and all necessary preparations were made to leave the anchorage. An anchor party was called forward and commenced raising the anchor. At 4–5 shackles on deck the windlass stopped and the anchor cable could not be raised any further. A short moment later, heavy seas hit the vessel's bow and the anchor cable began to run out. The hydraulic motor of the starboard windlass sustained damage, and shortly afterwards the bitter end of the anchor cable was jerked from its mounting. The starboard anchor and the entire cable dropped into the sea. The vessel remained adrift in a safe location. The consequential damage and injuries were reported as follows:

There were no injuries to the personnel. The crew did move to a safe location, but it was a close call with components being flung through the air when the windlass failed. The starboard anchor and a full 14 shackles length of anchor chain were lost to the sea. The hydraulic drive system to the starboard windlass and mooring winch (including hydraulic motor and planetary gear) were damaged. The cover bolts sheared off for the bitter end arrangements for the starboard anchor. The starboard anchor chain stopper dog was grooved. Both the dog hinge and dog securing pin were bent. The starboard anchor hawse pipe railing on the deck was damaged. In addition it an indentation was observed in the forecastle deck close to the hawse pipe entry. In this scenario the following direct and root causes were notified:

- Machinery and equipment breakdown or failure. Loss of starboard anchor and starboard anchor cable. Damage to starboard windlass hydraulic motor. Damage to starboard bitter end arrangement. Damage to starboard anchor cable stopper bar and hawse pipe railing.
- Adverse weather and/or sea conditions. Heavy seas and strong winds. Movement of vessel, stress on vessel equipment.

- Inadequate preparations and planning. Inadequate hazard identification.
- Incorrect use of equipment. Too late operation of main engines to assist anchor party in raising the anchor in fast deteriorating weather. Incorrect operation of the windlass hydraulic motor with too high tension on anchor cable.
- Inadequate supervision. Improper or insufficient delegation. Lack of precise instructions to the Officer on Watch (LOW) in case of deterioration of weather (wind force limits).
- Inadequate leadership. Inadequate identification and evaluation of loss exposures/risks. Bad weather forecast vs. remaining at anchor for planned repairs. Delayed decision to raise anchor and delayed use of main engines to facilitate raising of the anchor to leave anchorage.

Case 3: Grounded after anchor drag. A Suezmax tanker was involved in a marine incident, resulting in hull damage due to bottom grounding. The incident occurred whilst the vessel was weighing its starboard anchor in order to proceed to sea and drift due to bad weather. With the anchor aweigh and the engine running ahead, they attempted to turn the vessel to starboard, but it drifted on to the shore and ran aground in shallow water. All crew on board were safe, accounted for and remained on board the vessel. A damage assessment found that the 4 port water ballast tank level was dropping, there was water ingress into the pump room and the heavy fuel oil overflow tank was breached. However, no oil pollution incident was recorded. The bilge holding tank was also breached. The vessel had no cargo on board. Damage to the hull was confirmed but the vessel remained in a stable condition. After re-floating and re-anchoring, a hull damage and in-water bottom survey was carried out by an approved diving company.

The survey recorded a number of cracks and indents on the flat bottom centre line, close to the bilge holding tanks, engine cofferdam, heavy fuel oil overflow tank, pump room, 4 double ballast water tank port and starboard. No internal examination of the tanks was carried out, whilst at anchor, due to the flooding. A relevant class condition for the hull damage was issued. The rudder was tested in operation and no abnormalities found. The rudder blade bottom plate was found to be indented. All cargo and ballast pumps were submerged due to the flooding in the pump room. The vessel was towed to a shipyard for dry-docking and costly repairs.

For this scenario the following direct and root causes were identified:

- Inadequate leadership as the main root cause. The Master failed to ensure effective implementation of Bridge Resource Management (BRIM) and navigation practices.
- Inadequate identification and assessment of risk (not taking into consideration the weather forecast).

- Adverse weather and/or sea conditions. Wind (sail) effect on the hull/superstructure, loss of manoeuvring control/steerage. The adverse weather had a direct impact on vessel movement and ship handling.
- Failure to follow rules and regulations. Selection of anchor position and scope of cable against the company procedure and BRIM requirements. No adequate anchor watch, no adequate record keeping, failure in position verification etc.
- Inadequate preparation/planning. Inadequate work planning and verification system in use. Failure to effectively plan the voyage as required by BRIM practices and company procedures. Inadequate anchor position and scope of cable selection. Inadequate notice for engine readiness. Inadequate planning of maintenance and testing of navigational equipment.
- Incorrect navigation or ship handling. Failure in effective navigation and ship handling, as required by BRIM practices and company procedures. Inadequate BRIM. Inadequate anchor position and scope of cable selected. Inadequate notice for engine readiness. Inadequate anchor position fixing and monitoring. Incorrect use of equipment. Use of inherently hazardous methods/procedures/practices, e.g. over-reliance on ECDIS and radar for position monitoring, while verifying the anchor position the positions were not physically plotted on the chart, the anchor watch feature on GPS units not in use, of the three GPS units on the bridge only one unit was switched to DGPS mode etc.
- Lack of knowledge or skill / lack of experience. Whilst the Master was an experienced captain, it appears that he was not given the level of support that is essential from the bridge team (inadequate anchor position monitoring, inadequate record keeping, inadequate use of bridge instruments etc.).

2. ANCHOR PROCEDURE AND HUMAN FACTORS

The detailed analyses of any marine accident [EMSA 2017; Teekay internal document 2017; Health and Safety at Work 2018; NOAA 2018; UK Government Services and Information 2018] may result in a very long list of typical human factors (errors) that can and still cause significant numbers of similar marine accidents. Human factors have been defined as the characteristics of a job, individual or organization that influence human performance. In fact, we should also demonstrate a clear understanding that experienced, competent, well-motivated personnel and contractors are prone to errors of action and, under certain circumstances, may not follow procedures.

Anchoring must be pre-planned in detail, and a pre-anchoring meeting must be held to ensure complete understanding by everyone involved in the anchoring operations. For deep water anchoring, the chief officer must be in-charge of the anchor party. Additional officers may be present for training purposes only and, if trained to the master's satisfaction, may supervise shallow water anchoring in calm weather conditions. It is also very important to allocate sufficient and knowledgeable persons to carry out the operations from the forecastle. A job hazard analysis or 'toolbox talk' must occur before anchor operations.

When anchored, in the case of any anticipated deterioration in weather, the master is urged to make an early departure from anchorage to sea rather than risk damage or difficulties later. Due regard should be taken of weather conditions and anchoring avoided in rough seas or heavy swells. Clear instructions to the bridge and engine room staff concerning main engine readiness in case of weather deterioration (wind force criteria) must be discussed with the duty officers and duty engineer. The officers on watch must review the anchor practices procedure and ensure that it remains available with the master night orders in case of anchor watch.

In fact, the crew must ensure that the anchor and associated equipment are inspected, operated and maintained efficiently (including the lubricating program for the windlass, correct brake adjustments and ensuring the brake band thickness is adequate). The primary method of securing the anchor and cable for sea passage is to use the anchor windlass brake and a lashing arrangement. The secondary method is to use the anchor stopper bar and pin. If the stopper bar cannot be lowered into position and secured with the pin when the anchor is fully housed, due to wear on the anchor chain, leave it in the open position and secured.

The anchor party must ensure the anchor is fully housed by verifying that both anchor flukes are resting against the side shell. Apply the anchor windlass brake fully. Secure the anchor with appropriate wire lashings and turnbuckles. Ensure that the anchor lashing arrangement has adequate strength: it must be twice the weight of the anchor plus 10 m of the anchor chain length. Lower the anchor stopper bar / guillotine into place and insert the securing pin. After experiencing heavy weather, inspect the anchor lashing arrangement, and re-tighten if required.

For example, for a 17800 kg normal stockless anchor on a VLCC with 10 m of grade 3 chain of 102 mm diameter weighing 2326 kg, the required minimum breaking load (MBL) of the lashing wire would be: $(2 \cdot 17\,800 \text{ kg}) + 2326 \text{ kg} = 37\,926 \text{ kg}$ or 37.9 t. This equates to a steel wire rope 24 mm in diameter and equivalent turnbuckles.

The officers and crew forming the anchoring party forward must be trained and understand every aspect of the operation. Be aware of the variance in the capacities of the windlass, including hydraulic motors and anchor brakes, and use them judiciously. The International Association of Classification Societies (IACS) formula for anchoring equipment is based on an assumed current speed of 2.5 m/s (4.9 knot), wind speed of 25 m/s (48.6 knot) and a scope of chain cable between 6 and 10 shackles. The designed lifting capacity of the windlass dictates the appropriate depth of anchor.

Most windlasses are designed to lift only 3 shackles of cable along with the weight of the anchor, when the chain is up or down with no weight on it. The windlass motor is designed to correspond to the design lifting capability of the windlass. The motor is vulnerable to high loads and snap loads, especially if hydraulic powered. A cable stopper (pawl or guillotine) has twice the holding power of the brake, and the brake (in good condition) is about 12 times stronger than the motor.

The holding power of an anchor depends largely on the nature of the seabed, or holding ground. Certain types of mud and clay provide the best holding ground, while rock provides the worst.

Seabed conditions must be balanced with other factors, such as the water depth and the prevailing weather conditions. In strong winds, an anchored vessel will yaw, and at higher wind speeds it is increasingly likely to surge rapidly from one extremity of the yaw to the other. This can place a shock load on the anchor cable, breaking the anchor's hold in the seabed, and increasing the risk of anchor dragging. An anchor will drag when the tension in the anchor cable exceeds the total holding power of the anchor and the cable. An anchor provides maximum holding power when its flukes are fully embedded in the seabed. This occurs when the anchor shank lies on the seabed and the anchor cable pulls horizontally at the anchor shackle. When the pull increases, the cable lying on the seabed is lifted, creating an angle between it and the horizontal. As the angle increases, the total holding power reduces. A rule of thumb is that a pull at 5 degrees above the horizontal reduces the holding power by 25% and a pull at 15 degrees reduces the power by 50%.

Anchors and associated equipment are intended to work effectively in normal or good conditions. Therefore, anchor holding power calculations or estimates should not be used to determine the maximum wind speed or weather conditions in which a vessel can safely remain at anchor. Always pay attention to the nature of the bottom and depth contours while anchoring. Even with good holding ground, if the cable is not lying on the ground properly due to the depth contour, the anchor could still drag.

To maximize an anchor's holding power, the scope (length) of the cable should be sufficient to ensure that, in fair weather; a length of cable will lie along the seabed and pull horizontally at the anchor shackle. When this occurs, the cable rises gently in a curve to the hawse-pipe. The curve, or catenary, is necessary to ensure that the cable exerts a horizontal pull on the anchor shackle. This absorbs any shocks when the forces of wind, tide and current increase the pull on the cable.

The cable scope is the key in establishing a catenary. Most large ships are fitted with about 12 to 14 shackles, approximately 330 m to 385 m, of cable for each anchor. The common formula based on [Teekay internal document 2018a] for calculating the minimum number of shackles required for calm weather is: number of shackles of cable = 1.5 x √depth of water in meters. For large vessels, the cable scope is normally 6 times the depth of water while loaded and 7–8 times the depth of water while in ballast.

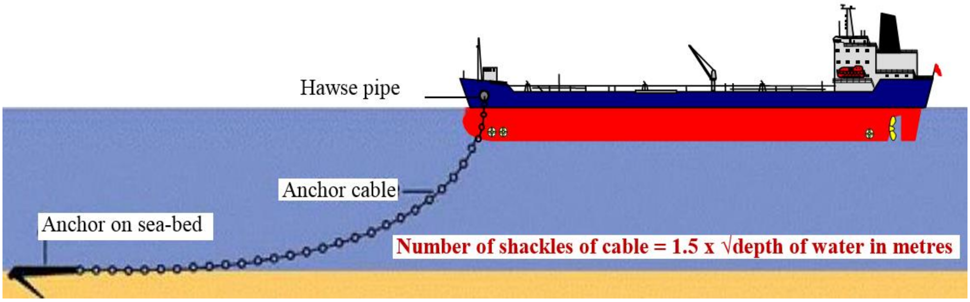

Fig. 1. To maximize an anchor's holding power; the cable length should be sufficient to ensure that, in fair weather, a length of cable will lie on the sea-bed and thus pull horizontally at the anchor shackle

Source: own study.

Many accidents have occurred while anchoring in difficult conditions or in deep waters when the tide/wind changes. The cause is usually misjudging the vessel speed while trying to control its movement over the ground by using engine ahead or astern. If there is a strong onshore wind and the anchorage is close to shore, consider not anchoring. If possible, maintain more than 1 nautical mile from any shallows or other potential hazards. For deep water anchoring, carry out a job hazard analysis. After experiencing heavy weather, inspect the anchor lashing arrangement and re-tighten if required.

The master should also try to avoid walking back the cable after the anchor has reached the seabed, because it is extremely difficult to judge the vessel's movement over the ground, and a slight error in judgment can cause serious damage to the windlass motor and associated anchoring equipment (cases 2 and 3). However, if the master decides to walk back the anchor on the seabed he should maintain the vessel's position when the anchor reaches the seabed. After this maintain a very minimal way over the ground. Closely monitor any strain on the cable and keep only one hydraulic pump in operation to prevent over-speeding of the hydraulic motor.

According to BRIM requirements and company anchor use procedures [Teekay internal document 2018a,b] to maximize an anchor's holding power, the scope of the cable should be sufficient to ensure that, in fair weather, a length of cable lies along the sea-bed and thus pulls horizontally at the anchor shackle.

When this occurs, the cable rises gently in a curve to the hawse-pipe. The curve, or catenary, is necessary to ensure that the cable exerts a horizontal pull on the anchor shackle. This absorbs any shocks when forces on the vessel, due to wind, tide or current, increase the pull on the cable.

While finally anchoring, the scope of the cable chosen in case 1 (9 to 10 shackles) and case 2 (12 shackles) was fine; however in case 3 (5 shackles in the water) was inadequate for the 40 m depth and the company anchoring procedure [Teekay internal document 2018a,b]. Using the common formula for calculating the minimum number of shackles required in case 3 for calm weather (= 1.5 x √depth of water in meters) gives 9.5 shackles in the water. In case 3, the master lifted the anchor with only 5 shackles in the water. Later the next day the cable veered to 7 shackles in the water and shortened to 7 shackles on deck – all still less than minimum required 9.5 shackles.

In loose terms, with an anchoring depth of 40 m and 6 shackles on deck, the cable will become tight when the vessel moves only 160 meters (65% of the vessel's length), thereby lifting the shank from the seabed. The lifting of the shank from the seabed decreases the holding power of the anchor significantly: when the shank is lifted to a 5 degree angle with the bottom the loss of holding power is 25%, while at 15 degrees the loss is about 50%.

According to the company 'use of anchors procedure' [Teekay internal document 2018a,b], where the master is concerned about the safety of the vessel with regards to the proximity of other vessels, the depth or the nature of the bottom, then engines should be kept in readiness on standby or short notice (10 minutes), as appropriate. After anchoring, the main engine in cases 2 and 3 was put on 'normal' notice, which in some cases could not mean the same as 'standby' or 'short notice', to allow the main engine to be made ready within 10 minutes. Whilst in this case the engine was on 'short' notice and the engineer was able to prepare the engine in a very timely manner, masters should be made aware of the need to discuss the situation with the C/E (i.e. teamwork) when deciding at what notice the engine should be. Some circumstances may demand that the engine room is manned with the engine ready to go immediately.

However, in the specific situations described in cases 2 and 3 it is very difficult to explain what should be the best solution to avoid dragging the anchor. According to the company 'use of anchors procedure' [Teekay internal document 2018a,b] in the case of dragging the anchor, while the anchor is still holding the seabed well, paying out additional cable should be done in anticipation of anchor dragging. If an anchor has dragged, even if the dragging has been controlled or ceased, lift the anchor and repeat the anchoring process. In such circumstances, if deemed necessary, vacate the anchorage. When there is difficulty in getting underway, consider use of the other anchor to prevent the vessel dragging into danger. Taking into consideration all the above we must comment that the decision by the captain in cases 2 and 3 to weigh anchor and anchor again or to go to open sea was correct, but most probably implemented too late.

In some cases, many activities were noted on the bridge. The master was observing the swinging circle plotted on ECDIS. He was operating the VHF and the engine telegraph. The master undertook several VHF calls himself, a possible source of distraction and loss of situational awareness. In case 3, the LOW was working to the master's instructions; however, from the interview with the master it was noted that after the grounding the support to the master by the duty officer on the bridge was poor. Seemingly the shock rendered the LOW completely ineffective.

The importance of calling the master in good time cannot be stressed enough, as is the importance of keeping a proper anchor watch – all the best watch keeping practices should be followed if the vessel is underway or at anchor. In future, having a contingency plan available should be taken into consideration, to cover leaving the anchorage in an emergency. It such a specific situation (e.g. case 3), the following could also be considered: why not veer more cable when already dropping astern, and when the weather deteriorated why was the decision not made then to weigh anchor and sail? Taking into account the original anchor position, with the wind from the north an extra 2 shackles veered would have allowed the vessel to slip further astern, while if the wind came around to the east it would move the stern closer to danger. Was dropping a second anchor considered? Why not, with 2/3 shackles on deck while weighing anchor to proceed to sea, drive the vessel ahead and away from danger using the engine. With 3 shackles on deck this should be possible if sufficient power is applied. When using the main engine to avoid grounding, (when asked) the master did not consider using the load-up programme override button to get the engine to maximum rpm rather than leaving her at manoeuvring full ahead. To reduce the yaw, the possibility of lowering the port anchor to the seabed should have been considered. Tugs should have been called at an earlier stage, i.e. before grounding. Rather than having the helm hard-a-starboard, it would have been more effective to reduce the helm, to say starboard 20°, which would allow more propeller discharge current to drive the vessel ahead rather than drive her into the turn.

When nearing the shoal contour with the anchor still on the bottom and hard to starboard helm and ahead on the engine, the vessel's pivot point was at the hawse pipe thereby giving a very strong turning effect to swing the stern starboard through greater lateral motion than at the bow, therefore putting the stern closer to the danger area.

Each of the cases highlights the importance of maintaining situational awareness at all times, especially when close to danger. The LOW must provide the master with regular status updates – distance to dangers, COG/ SOG. All electronic navigation aids, such as the gyro, radar, GPS and chart plotting device, must be tested and set up by the watch-keeping officer to ensure that they are accurate and in full working condition.

The master and officers should be completely familiar with the corrections to be applied to these systems and of inherent limitations that affect the accuracy of the individual systems. Reliance on any one system alone could lead to a significant navigational error. An integrated approach should be used, with at least two systems, to verify the accuracy of the vessel's position. The vessels from our cases were not equipped with ECDIS, only an ECS Navigation System with raster charts (not frequently updated) for reference use only. Whilst radar and ECDIS are valuable navigation tools, complete reliance must not be placed on them. Whilst paper charts were the primary navigation system, ECS could have been to help maintain situational awareness.

Visual and radar position fixing and monitoring techniques should be used whenever possible. It means that frequent checks should be made even of the ECDIS position fixing system (normally GPS) by the use of radar, to check the accuracy of the charted position by comparing the location of the radar target against the charted symbol plus parallel indexing and/or use of clearing radar bearings and/or distances.

In the master's night order book from case 3, there was a record that the officer of the watch needs to call the captain when the distance to the nearest danger drops to 5 cables or less. However, the position noted by the master in the same night order book was already only 3.7 cables from the shallow water counter (nearest danger). At that time, the position was also not plotted on the paper chart. For verifying the anchor position, the 10 cm radar and GPS/ECS systems were in use.

In all the cases the positions recorded in the anchor watch form were based only on the GPS system (Furuno DGPS Navigator GP-80 set up for GPS or DGPS mode in WGS84 datum). In practice there was no evidence that the GPS positions were compared between different GPS units.

Each GPS unit was equipped with an application for anchor watch and a DGPS mode, which is free of charge. In case 3, DGPS mode was not activated on two GPS units, and the anchor watch mode was not activated on any of the GPS units. It was also noted that some junior officers were not fully familiar with navigational systems available on board, and there is no evidence that this application was in use before. From interviews it was noted that only one GPS unit was used for the anchor position watch, along with X-band radar and for reference the ECS system. In fact, detailed analyses of any marine accident always includes a very long list of human errors that led to the event, including those considered here, related to anchoring and manoeuvring the vessel at the anchorage.

3. CONCLUSION

In each of the cases, all deck and machinery equipment was reported to be in good working order. Fatigue was also not a contributing factor. Key personnel were tested for drug and alcohol contents immediately after the incidents, and all result showed negative. In all the cases the specific company anchorage procedure was implemented, but the main cause of the accidents was a failure to follow a safety procedure.

Other issues also noted include inadequate supervision, lack of knowledge or experience, inadequate identification and assessment of the risk for the anchor position, the scope of cable chosen, and the failure to make adequate provision for the forecasted weather. In some cases it was also noted that communications on board was inadequate and should be improved (e.g. a better understanding between the bridge team and anchor team (cases 1 and 3), ship team and shore team (case 2), the master and chief engineer as to what notice is required for the main engine in cases 2 and 3, etc.).

In fact, it is a management role to guide masters and chief engineers and provide adequate tools to minimize the impact of these events by supplying sets of simple rules eliminating the 'hesitation and/or delayed reaction factor'. Straight instructions are recommended. Do not anchor or leave anchorage immediately upon receipt of a severe weather condition forecast. Each case here highlights the importance of maintaining situational awareness at all times, especially when danger is close.

In such a case we recommend planning the anchoring well in advance, taking the following into consideration: available room at the anchorage, proximity of other vessels at anchor, areas to avoid, degree of shelter afforded, proximity to land or other dangers, length of stay at the anchorage, prevailing and forecasted weather, local tides and currents, their direction and strength, water depth, nature of the holding ground (bottom), the possibility of underwater obstructions, emergency and contingency situations, any vessel constraints, approach speeds and direction, suitable communication with the anchoring party, navigational warnings, charts, and the inclusion of any cautions noted. If required, the ship team should carry out a job hazard analysis or toolbox talk. If a pilot is on board, the master should discuss the anchoring plan as part of the overall passage plan. The master must be in full agreement with the plan, including the choice of anchorage, approach, scope of chain to be used and the resulting distance from any other vessel or navigational danger when the vessel is brought up to anchor. The master must be aware that even a well-sheltered anchorage can become exposed with a rising sea state and an onshore wind, especially once the anchor starts dragging, the vessel may move at considerable speed.

Prior to approaching the anchorage, the leader of the anchoring party should be provided with suitable instructions and guidance. The master must explain in detail the anchoring method, options, limitations of the equipment and safety parameters. Test the thrusters (if available) at a safe speed. Test communications with the anchoring party well in advance. Decide upon any alternative anchorage to be used well in advance. In case of an emergency or sudden onset of onshore heavy weather, it may be wise to leave the anchorage. If there is a strong onshore wind and the anchorage is close to shore, consider not anchoring. On a VLCC vessel, if possible, maintain a distance of more than 1 nautical mile from the shallows and other potential hazards.

At the anchorage location, release the anchor (just above the water level in shallow water, or close to the seabed in deep water). Once the vessel is brought up and excess weight on the chain has been eased, apply the anchor windlass brake fully (if possible while the cable is vertical and without any weight on it). Lower the cable stopper bar (pawl/guillotine) into place, maintaining a gap of 5–10 cm between the link and the bar. This gap will ensure easy lifting of the bar in an emergency. Insert the securing pin. If necessary, engage the anchor windlass gear and adjust the anchor chain position. Under normal anchoring conditions in shallow water, walk back the anchor under gear to a position just above the water level before releasing the brake. Do not drop the anchor from its stowed position in the hawse pipe, except in an emergency.

For deep water anchoring, walk the anchor back to a position close to the seabed before releasing the brake, to avoid damaging the anchor. While walking back, the vessel should ideally be stopped, or at maximum speed of 0.2 knots or less. Disengage the anchor windlass from the gear. Once the vessel is brought up to the anchor, establish an anchor watch. It is prudent to place a good mark on the anchor cable, visible from the bridge.

Occasionally, if the master deems it necessary, the anchor may be walked back under power with the windlass motor engaged. When doing so, keep a close watch on any strain coming on the cable and advise the master. If the strain on the anchor chain becomes high, consider ceasing to pay out the cable using the windlass motor. If deemed necessary, secure the windlass brakes, remove the windlass from the gear until the strain has been relieved, then consider paying out using the brakes. Try to avoid walking back the cable after the anchor has reached the seabed because it is extremely difficult to judge the vessel's movement over the ground, and a slight error in judgment can cause serious damage to the windlass motor and associated anchoring equipment (similar or worse than described in cases 1, 2 & 3).

However, if the master decides to walk back the anchor on the seabed, stop the vessel over the ground when the anchor reaches the seabed. Maintain very minimal way over the ground afterwards. Closely monitor any strain on the cable. Keep only one hydraulic pump in operation to prevent over-speeding of the hydraulic motor. In addition, the master must not dismiss the engine room personnel or anchoring party until the vessel is confirmed brought up to anchor and is maintaining a safe distance from the nearest danger.

When anchored, frequently monitor and record the vessel's position. Establish a swinging circle on the chart. Note the vessel's head and plot the vessel's position as soon the anchor is let go. Further ascertain the position where the anchor was let go by using the vessel's head and the bridge-bow length. Note the vessel's position and anchor position on the anchor watch record. From the anchor position, draw a circle with a radius of the vessel's length plus the length of the cable paid out. This establishes a swing circle at the anchorage position. Monitor the vessel's position at least once every hour, or as necessary under the prevailing conditions, and record the positions on the anchor watch record. To help establish a pattern of vessel behaviour while at anchor, make hourly entries at the same time on the anchor watch record of the following: vessel's head, wind (direction and force), current (speed and direction) and extremity of yaw (port and starboard). Increase the frequency of obtaining positions if the weather deteriorates, another vessel anchors in close proximity, the vessel yaws excessively or in any other circumstances where the vessel's position or safety is in any doubt.

In anticipation of anchor dragging, while the anchor is still holding the ground well, additional cable should be paid out. If an anchor has dragged, even if the dragging stopped or was controlled, lift the anchor and anchor again. In areas where dragging is occurring or there appears to be a high risk of dragging, vacate the anchorage if necessary. If there is difficulty getting underway, consider using the other anchor to prevent the vessel dragging into danger. And always remember to follow up the safe anchoring operation procedure.

REFERENCES

EMSA 2017, European Maritime Safety Agency, Annual Overview of Marine Casualties and Incidents, http://www.emsa.europa.eu/, April 2018.

Health and Safety at Work, 2018, Summary statistics for Great Britain, www.hse.gov.uk, April 2018.

NOAA, 2018, NOAA Incident News, htpps://incidentnews.noaa.gov, April 2018.

Teekay internal documentation from significant incident investigations carried out from 2010 to 2017, (e.g. No. 4460753), 2017.

Teekay internal document No. SP1571 Anchoring Practices (KTM), 2018a.

Teekay internal document No. SP1792 Navigation Handbook, 2018b.

UK Government Services and Information 2018, www.gov.uk, April 2018.