Accident
Investigation Board
Norway

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REPORT Marine 2019/07

REPORT ON MARINE ACCIDENT – THE GROUNDING AND FOUNDERING OF THE FFS ACHILLES OFF FARSUND ON 3 MARCH 2017

AIBN has compiled this report for the sole purpose of improving safety at sea. The object of a safety investigation is to clarify the sequence of events and root cause factors, study matters of significance for the prevention of maritime accidents and improvement of safety at sea, and to publish a report with eventually safety recommendations. The Board shall not apportion any blame or liability. Use of this report for any other purpose than for improvements of the safety at sea shall be avoided.

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This report has been translated into English and published by the Accident Investigation Board Norway (AIBN) to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

Photo of ferry on the Norwegian west coast: Bente Amandussen

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NOTIFICATION OF THE ACCIDENT

The Accident Investigation Board Norway (AIBN) was notified of a marine accident by the Joint Rescue Coordination Centre for Southern Norway (JRCC-S) on 3 March 2017 at 20.49. According to the notification, the tugboat FFS Achilles had run aground at Nordre Lamholmflua, a reef in the approach to Farsund, and foundered shortly thereafter. The three crew members had evacuated into the vessel's life raft before FFS Achilles sank.

On the same day, the AIBN decided to initiate an investigation into the accident. Three accident inspectors from the AIBN travelled to Farsund on 14 March to examine the vessel and conduct interviews.

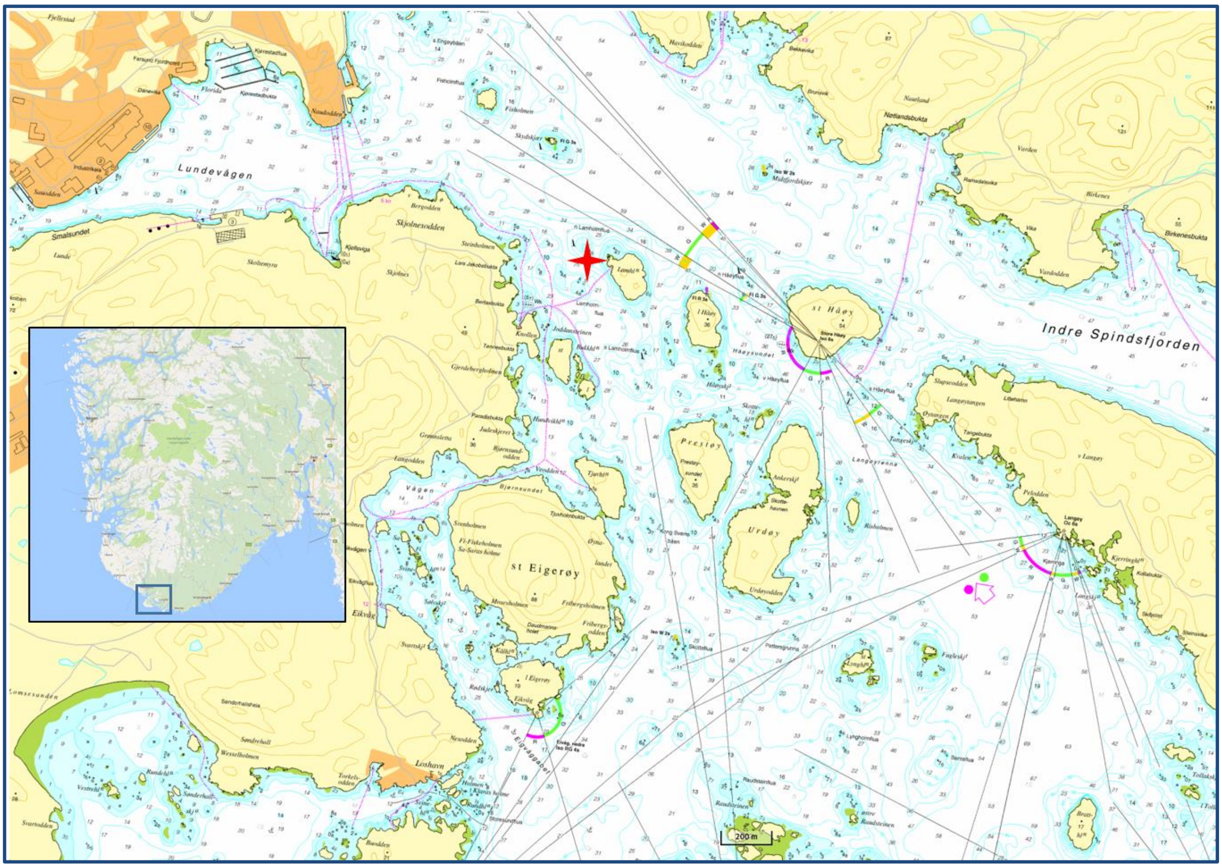


Figure 1: The accident site is located south-east of Farsund. Map: NCA/AIBN

SUMMARY

While returning to Farsund from an assistance operation in the Fedafjord on 3 March 2017, the tugboat FFS Achilles ran aground at Nordre Lamholmflua in the approach to Farsund. The vessel ran aground at a speed of 8.4 knots, and sank shortly thereafter due to damage to the bottom under the engine room. FFS Atlas arrived at the scene before the vessel sank and rescued its crew, who were in the life raft. Two out of the three crew members had suffered minor injuries and received medical attention.

The mechanical control system for the propeller units (Voith Schneider) on board FFS Achilles was controlled by autopilot. The navigator, who was alone on watch, has stated that he initiated a change of course to port on the autopilot to pass the green navigation marker at Nordre Lamholmflua on his starboard side. The autopilot did not respond, and he made several

unsuccessful attempts to initiate a change of course. He decided to deactivate the autopilot in order to switch to manual control, but the vessel ran aground before he could do so.

The investigation into the accident has not found any faults or defects in the propellers' mechanical control system, and the autopilot did not store data. The AIBN is therefore unable to explain why the navigator found that the system did not respond to the initiated changes of course. However, the navigator's statement does not agree with the vessel's course in the automatic identification system AIS. It may have contributed to the sequence of events that the floodlight was turned on at a later time than prescribed by the shipping company's procedure. There should also have been a dedicated lookout on duty to monitor the voyage.

With its single bottom and long engine room, FFS Achilles was vulnerable in the event of a grounding. The ingress of water through the damaged bottom exceeded the bilge pumps' capacity, and the intact water-tight compartments to the fore and aft of the engine room were too small to keep the vessel afloat. The investigation concludes that the current design requirements would not necessarily have made a new vessel of the same type as FFS Achilles, built for sailing under the Norwegian flag, any safer when the bottom was damaged. However, as a result of requirements stipulated by some flag states, the industry has developed a new design for a similar tugboat that would probably have survived the damage that sank FSS Achilles.

Based on this investigation, the AIBN submits one safety recommendation to the shipping company concerning procedures for bridge manning and sailing in narrow channels after dark.

1. FACTUAL INFORMATION

The factual information was obtained through interviews with the crew of FFS Achilles and the shipping company's management. The AIBN has also obtained information from the Joint Rescue Coordination Centre, the Norwegian Maritime Authority, the Norwegian Coastal Administration and the suppliers of the vessel's autopilot system and propulsion system. The vessel was inspected by means of a remotely operated vehicle (ROV) before she was raised. The AIBN carried out technical examinations of the vessel after the raising.

1.1 Sequence of events

FFS Achilles moored in Farsund at 05.50 on Tuesday 28 February 2017 after completing an assignment in Kristiansand. During the following days, the vessel remained moored and its crew carried out maintenance work during the day. In the morning of Friday 3 March, the shipping company phoned the vessel's navigator with information about an assistance operation in Kvinesdal later that day. The navigator and the shipping company agreed that the vessel would leave for Kvinesdal at 10.00. The general manager of the shipping company would join FFS Achilles in Kvinesdal and take part in the assistance operation.

The crew readied the vessel and left the quayside at 10.00 as agreed. At 13.15, FFS Achilles moored at the Kvina Verft shipyard. The general manager arrived, and the vessel departed at 15.15. Together with the tugboat BB Connector, FFS Achilles assisted the bulk carrier Ever Alliance during departure from the quay at Tinfos Jernverk. FFS Achilles returned to Kvina Verft at 16.45, and the general manager went ashore.

FFS Achilles was then to return to Farsund. At 17.55, the vessel had left the Fedafjord and was heading south along Listalandet at a speed of 8–9 knots. The voyage from Farsund to Kvinesdal had been planned in advance and plotted on the vessel's electronic chart display and information system (Transas ECDIS[1]). The same route was used on the return voyage. During the voyage, the navigator checked that he was on the correct route by looking at the chart plotter. A deviation of more than 0.3 cable lengths (55.5 metres) from the route would trigger a visual alarm on the chart plotter's screen.

The navigator was on the bridge and followed the planned route between Farsund and Kvinesdal, which would enter the approach at Loshavn and continue up the channel west of the islands of Prestøy and Lamholmen to the quay at Farsund. It was normal practice to sail with only the navigator on the bridge. According to the navigator, no written order or any other documentation existed to indicate a different bridge manning level during voyages.

The other two crew members came up to the bridge at irregular intervals to 'have a chat'. The able seaman left the bridge approx. 10 minutes before the vessel arrived at Farsund. It was dark at the time. The weather conditions at the time of the accident were south-westerly fresh breeze with some showers. The navigator felt that he had good visibility from his position and that there was no background lighting on the bridge that reduced visibility.

When the vessel was approaching the area west of Lamholmen islet, the navigator had lit the floodlight to see the reflectors on the two navigation markers that marked the reefs at Vestre Lamholmflua and Nordre Lamholmflua. These markers were not fitted with lights. At that time, visibility was good and he claimed that he had observed both markers. The vessel was on autopilot, as was normal.

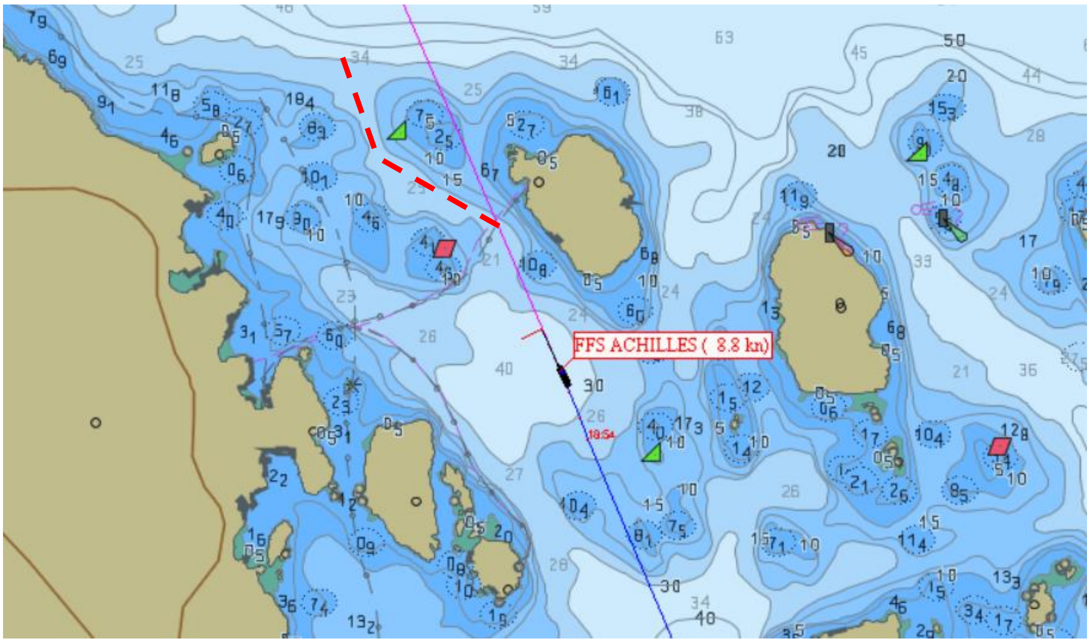


Figure 2: FFS Achilles' voyage towards the area west of Lamholmen. The dotted red line shows the planned course. Source: NCA AIS/AIBN

[1] Not full Electronic Chart Display and Information System (ECDIS).

The navigator found the voyage perfectly normal until the moment when he was abreast of the red marker at Vestre Lamholmflua. There were no external distractions in the form of other vessels or phone calls. On passing this marker, he wanted to turn the vessel to port in order to keep the necessary distance to the green marker at Nordre Lamholmflua, see Figure 2.

The navigator had positioned himself at the centre of the wheelhouse to maintain good overview during navigation. He believes that he had turned the driver’s seat so that its back was to port in order to ensure that he had a clear view forward.

When the navigator saw that he was abreast of the red marker at what he believes to have been a distance of approx. 10 metres, he moved the autopilot control stick (see Figure 3) a few times (clicks) to port and heard the sound that signalled a change of course. He found that despite this, the vessel did not change course. He had not observed any alarms or anything out of the ordinary before this. He moved the stick to port another few times without this resulting in a change of course.

The navigator then chose to move towards the autopilot to set it to manual and control the vessel manually using the steering wheel placed in front of the driver's seat. It was not possible to override the autopilot by turning the wheel. As he found that the vessel did not turn to port, the navigator also believes that he saw the manual steering wheel turn quite rapidly to starboard.

As the navigator was approaching the autopilot, FFS Achilles ran aground. The navigator was thrown over the manoeuvring handles and the manual steering wheel (see Figure 4) before hitting the fore bulkhead.

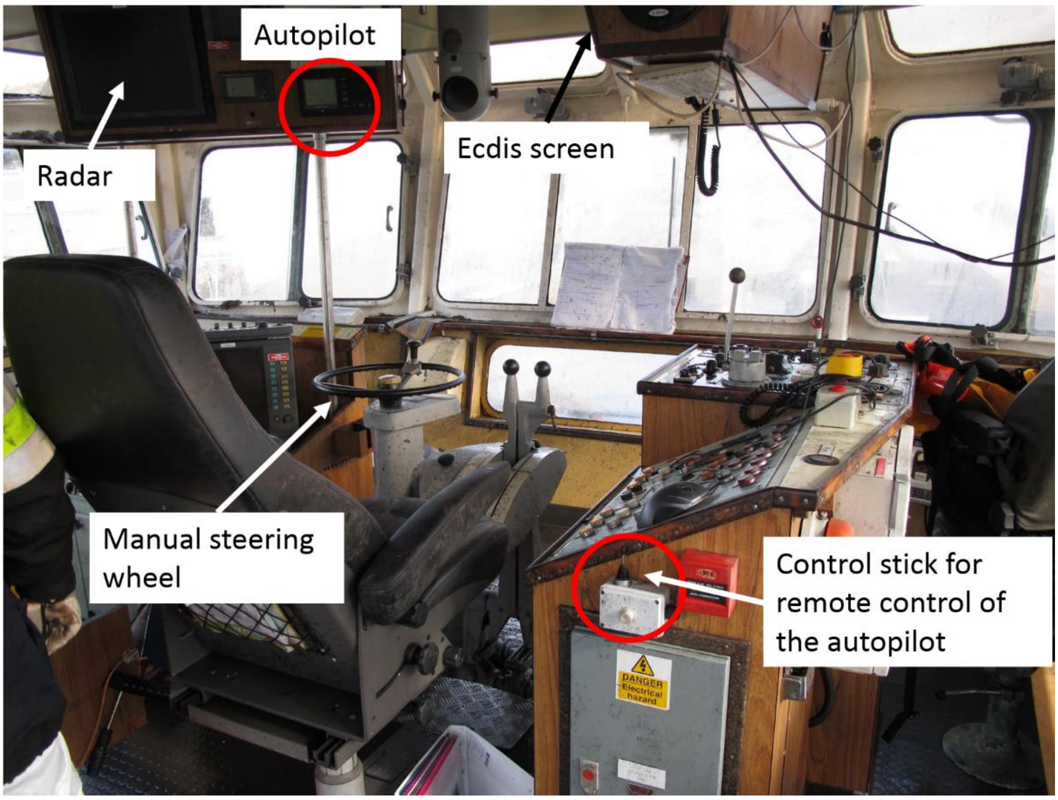


Figure 3: The wheelhouse interior. Photo: AIBN

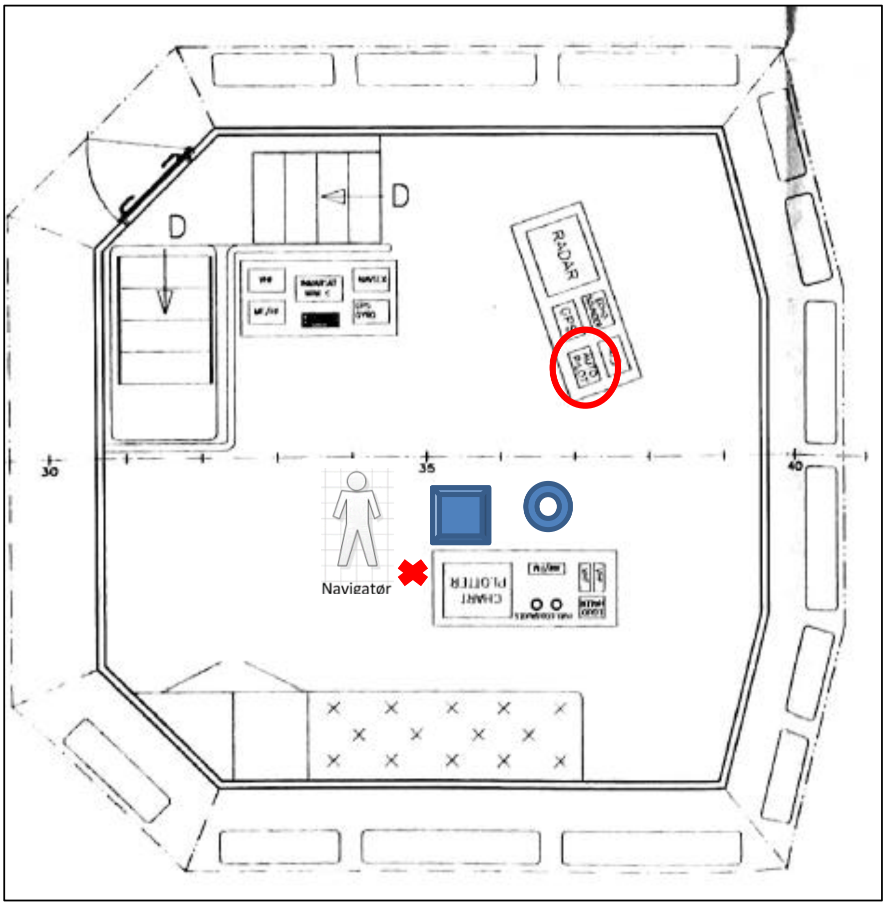


Figure 4: Plan of the wheelhouse showing where the navigator was standing shortly before the accident. The autopilot control handle is indicated by a red X. The autopilot is indicated by a red circle. The manual steering wheel is indicated by a blue circle. The seat is indicated by a blue square. Illustration: The vessel owners/AIBN

The vessel ran aground at a speed of 8.4 knots. An alarm went off on the bridge after the grounding, and the navigator believes that it may have been a bilge alarm. FFS Achilles stopped with a slight list to port. The navigator immediately tried to reverse the grounded vessel off, but found that the vessel's propulsion system did not respond. He did believe that he could hear the normal sound of one or both propeller units rotating, however.

1.2 Notification and rescue efforts

The navigator notified the shipping company's general manager that the vessel had run aground and requested assistance from the company's other tugboat to get FFS Achilles under control. At that time, he was not aware that the vessel was taking in water. He also felt that the vessel was firmly aground.

The able seaman was in the galley when FFS Achilles ran aground and cannot remember having observed anything out of the ordinary before the grounding. He was thrown against a counter by the impact and broke two ribs. Despite his injury, he quickly made his way to the engine room and found that they were taking in water. He observed that the chief engineer was already in the engine room. The able seaman saw that the water level in the engine room was above the floor plates, put on a lifejacket and ran up to the bridge to inform the navigator. The chief engineer also came to the bridge to report the situation in the engine room.

The navigator made another call to the shipping company's general manager to report that they were taking in water. He was told that the general manager would come out on the company's other vessel to assist them.

The able seaman then started readying the man overboard (MOB) boat at the order of the navigator. This was done to have an alternative to keeping FFS Achilles in position while they were waiting for the company's other tugboat to reach them.

Somewhat later, the navigator found that the vessel slipped off the skerry and started drifting. He then left the bridge to assist the able seaman in launching the MOB boat. Because the vessel was listing, the wire cut into the block and the MOB boat could not be lowered. The able seaman has indicated that he and the navigator were engaged in this work for 5–10 minutes.

The chief engineer was in the cabin when FFS Achilles ran aground. He immediately made his way to the engine room to check the situation there. When he arrived, he found that water was coming in through the bottom of the vessel. He went to the bridge to inform the navigator of this.

The chief engineer quickly returned to the engine room, where he started the other harbour generator to provide sufficient power to pump out water at the vessel's full pumping capacity, which was two standard bilge pumps. He quickly found that the bilge pumps could not keep up with the water ingress. Then he focused on preventing pollution should the vessel sink. When he found that water was entering the auxiliary engine room, he stopped both main engines and shut off the fuel supply from both starboard and port diesel tanks. When that was done, he went up on deck and saw that the other two crew members were working to launch the MOB boat.

He went to ready the fore life raft. He got the life raft out and inflated without any problems. After a while, the navigator and able seaman came to help, and the life raft was launched on the port side of FFS Achilles. The chief engineer and the navigator then went into the superstructure to collect the logbook and other documents.

By then, FFS Achilles had slipped off the reef, and the port list was increasing rapidly. The chief engineer soon exited the superstructure. By then, the vessel was listing so much that water had started to flood the main deck and run into the superstructure. The crew indicates a list of 30–35°. Both the able seaman and the chief engineer could just lie forward into the water and enter the life raft.

The navigator exited the superstructure as FFS Achilles started to sink. His foot was caught in the doorway to the main deck, and he was pulled down. After a while he managed to free his foot and floated up to the surface, where he was helped into the life raft.

Shortly thereafter, the shipping company's other tugboat arrived. The crew threw a line to the crew members in the life raft and pulled it away from FFS Achilles before she sank completely. Only the mast of FFS Achilles was visible at the time. The crew was brought ashore in Farsund, and the able seaman with broken ribs and the navigator who had injured his foot were taken to the hospital in Flekkefjord to be examined.

1.3 Personal injuries

Table 1: Personal injuries

Injuries	Crew	Passengers	Others
Dead			
Serious			
Minor/none	3		

1.4 Damage to the vessel

1.4.1 Important observations

The vessel was raised after foundering, and the AIBN conducted a technical examination on board. For detailed results of the technical examination, see Annex B and description of the raising in Annex C.

The AIBN reviewed the vessel's propulsion system together with the general manager of Farsund Fortøyningsselskap AS, who knew the vessel very well. The AIBN also conducted independent investigations. No visible damage or nonconformities were found in the mechanical control system from the wheelhouse through the superstructure down to the propeller units. Nor were there any visible damage or nonconformities in the mechanical part of the autopilot system.

Damage of relevance to the sequence of events was primarily observed on the foreship, the propellers, the propeller guard and the hull in the immediate vicinity of the propellers and propeller guard.

The following important observations were made after FFS Achilles had been raised and placed on the barge:

- The front of the foil (the 'foot' below the propellers) was damaged on the starboard side. It was obvious that this point had hit the reef.
- Several of the struts attaching the foil to the hull had been torn off at the point of attachment to the foil.
- The rear inner strut on the starboard side had broken off approx. 20 mm above the inside of the shell plate. The torn strut had moved downward in a way that tore open the shell plate and left a hole measuring approx. 250 x 300 mm. This hole opened the hull into the engine room.

The following observations were made concerning the propeller blades and thrust direction:

- Seen from above, the starboard propeller unit normally rotated clockwise and the port unit anticlockwise.
- The blades on the port unit were in the neutral position, i.e. not producing thrust in any direction.

- Except for one bent blade that had turned in the opposite direction to the other ones, the blades on the starboard unit were in a position that would have produced forward thrust.

Figure 5: The rear inner strut on the starboard side had torn open the skin of the hull. Photo: AIBN

1.4.2 Propeller units

The AIBN has presented the sequence of events and its findings concerning the propeller units to the company that designed and manufactured the vessel's propulsion systems, Voith Turbo GmbH & Co. KG of Heidenheim, Germany. Voith Turbo confirms that, at the moment of impact, the units had 65% driving pitch forward and 0% rudder pitch as indicated by the indicator point on top of the starboard unit (ref. Annex B).

Voith Turbo points out that it is probable that the starboard unit 'jammed' when the foot of the propeller guard hit the reef and the forward edge was knocked upwards. This damaged the unit and caused it to stop. Voith Turbo states that the blades of the port unit probably assumed the neutral position (zero pitch) when the engines were shut down. The explanation given for this is that the push-pull rod that pushes/pulls the arms that turn the propeller blades is spring-loaded, which ensures that the unit will go to the zero pitch position if it loses hydraulic oil pressure. The oil pressure was lost when the main engines were turned off.

Voith Turbo also pointed out that the damage to the port unit was unlikely to have been sustained before the vessel ran aground.

1.5 Weather and sea conditions

The Norwegian Meteorological Institute has two weather stations near the position where the vessel foundered. Information from the online weather service yr.no shows that during the period when FFS Achilles foundered, Lista was experiencing west-south-westerly wind with a mean wind speed of 4.7 m/s and the strongest gusts reaching 8.2 m/s. During the same period, Lindesnes was experiencing south-westerly wind with a mean wind speed of 8.0 m/s with the strongest gusts reaching 11.5 m/s.

Water level data from the water level and tidal information website vannstand.no indicates that FFS Achilles sailed through Prestøysundet sound just after high tide in the area on the day of the accident.

The AIBN has not obtained information about the current conditions in the area.

1.6 The voyage based on AIS data

1.6.1 Introduction

The AIBN obtained the AIS data registered for FFS Achilles on the day of the accident from the Norwegian Coastal Administration. The information has been entered into the map system MADAS and presented as shown in Figure 6. The figure shows the AIS track of FFS Achilles' voyage from Farsund (at the top of the map) bound for Kvinesdal earlier on the day of the accident. The map in Figure 6 also shows the AIS track of the return voyage. The AIS data show that the speed was about 8.5 knots right up to the time of the grounding.

1.6.2 Changes in course, rate of turn and distances

Course values described in this section are based on the course over ground (COG) sailed by FFS Achilles as shown by AIS data. After passing Skotteflua beacon heading north, the vessel turned to port to continue up Prestøysundet sound in a north-north-westerly direction. The change of course was 24° with a rate of turn of 0.39°/sec. At 19:51:38, the vessel was heading directly towards the red navigation marker at Kong Sverre båen reef, and the distance to the marker was 119 metres. FFS Achilles then changed course 12° to starboard at a rate of turn of 0.54°/sec. and passed the marker aport at a distance of 22 metres.

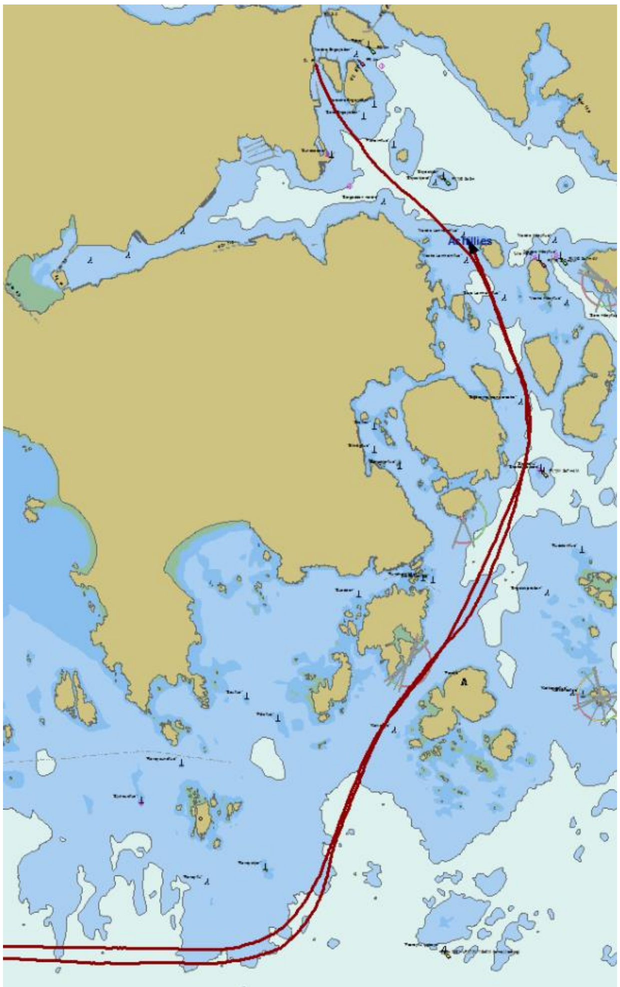


Figure 6: FFS Achilles' voyage to Kvinesdal and back. Source: AIBN

The vessel turned again after passing the red marker, 24° to port, and was back on course up Prestøysundet sound. The rate of turn during this manoeuvre was 0.68°/sec., the highest rate during the final six minutes before the grounding.

Figure 7 shows the AIS tracks from the final part of the voyage until FFS Achilles ran aground at Nordre Lamholmflua. After sailing a little west of the track from the outbound voyage, the vessel crossed its outbound track at 19:54:33, when it was roughly abreast of the green marker at Søre Lamholmflua (bottom right on the map). This was 1 minute and 42 seconds before the grounding.

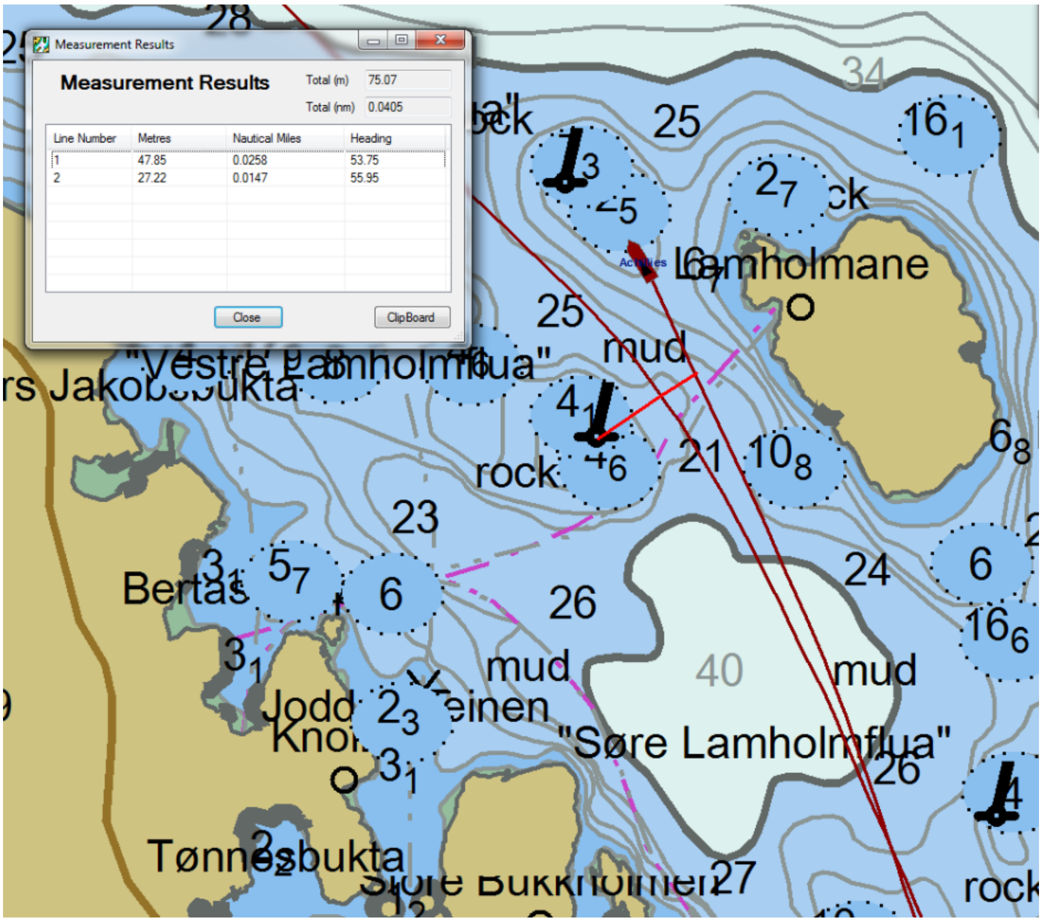


Figure 7: AIS tracks for the final part of the voyage. Source: AIBN

As shown by the figure, the vessel then sailed increasingly further east than she did on the outbound voyage from Farsund. Over the distance from the green marker at Søre Lamholmflua to the position abreast of the red marker at Vestre Lamholmflua, the vessel's course gradually changed 7 degrees to port. The figure shows that when she was abreast of the red marker, the distance between the vessel and the marker was 75 metres (line number 1+2). The vessel passed 27 metres further east than on the outbound voyage, or 75 metres from the marker (line number 2).

When FFS Achilles was abreast of the red marker at Vestre Lamholmflua, it was 130 metres away from the reef at Nordre Lamholmflua, a distance that the vessel travelled in 31 seconds. The vessel turned one degree to starboard during the first 10 seconds after passing the marker, which gives us a rate of turn of 0.1°/sec.

During the final 21 seconds before it ran aground, the vessel's course changed 6° to port at an average rate of turn of 0.28°/sec. The highest rate of turn during this period was 0.67°/sec. (2° to port in three seconds).

1.6.3 Heading and course over ground

The AIS tracks shown in Figure 6 and Figure 7 are the sailed course over ground (COG). The AIS information also contains the heading (HEADING).

Up along Sandøya island, the HEADING was to the port/west of COG. Until passing Skotteflua beacon where the change of course towards Kong Sverre båen reef took place, the HEADING was primarily to the starboard/east of COG with an average difference of 2.0°. After passing the red marker at Kong Sverre båen reef and continuing up Prestøysundet sound, the HEADING was to the port/west of COG until the vessel ran aground.

The average difference between COG and HEADING during the final part of the voyage through Prestøysundet sound was 2.3°. During the final 31 seconds (from when the vessel was abreast of the red marker at Vestre Lamholmflua until the grounding), the average difference between COG and HEADING was 1.8°.

1.6.4 Grounding, drifting and sinking

When FFS Achilles had approx. 0.8 nautical miles left to the quay at Farsund, she ran aground at Nordre Lamholmflua at 19:56:15 with SOG 8.4 knots, COG 327° and HEADING 326°. Three seconds later, SOG was 1.5 knots, COG 338° and HEADING 332°. After another three seconds, SOG was 0.7 knots, COG 343° and HEADING 338°. This indicates a significant and fast turn to starboard when the vessel hit the reef.

After a relatively short time, the vessel slipped off and started drifting in a south-south-westerly direction. Two minutes after running aground, the vessel was 15.5 metres west and 32 metres south of the position where she ran aground. She then drifted in a westerly direction for 1½ minutes before starting to drift north-north-westward. The bow (HEADING) was pointing more or less north-west the whole time.

FFS Achilles sank at 20.34 approx. 180 metres north-north-west of the position where she ran aground. The vessel had then drifted at an average speed over ground of 0.18 knots (0.09 m/s).

1.7 The crew

The crew on board FFS Achilles at the time of the accident consisted of three men, all Lithuanian nationals.

The navigator was 34 years old and held a Lithuanian deck officer certificate as *Officer in charge of a navigation watch on ships of 500 gross tonnage or more*. The certificate was valid until 10 June 2019 and had been endorsed by the Norwegian Maritime Directorate: Deck Officer Class 4.

The navigator had been employed by Farsund Fortøyningsselskap AS since 2010. He was awarded his deck officer certificate in 2014 and had been rated as captain for the shipping company's vessels in 2015. He had not been cleared as captain for towing and assistance operations, meaning that he could act as captain of the tugboats on the way to and from assistance operations as he did on the day of the accident. He had sailed FFS Achilles through Prestøysundet sound as captain (alone) approx. 30 times.

The chief engineer was 66 years old and held a Russian chief engineer certificate. The certificate was valid until 16 May 2019 and had been endorsed by the Norwegian Maritime Directorate: Engineer Officer Class 1 Motor.

The able seaman was 55 years old and held a Lithuanian qualification certificate as an able seaman.

All the crew members held valid medical certificates.

1.8 Craft and equipment

1.8.1 General information

The tugboat sailed under the British flag from the time she was built in 1984 until 2010. Under the British flag, the vessel had the names Lady Stephanie and Svitzer Stephanie. In 2010, she was bought by Farsund Fortøyningsselskap AS and registered in the Norwegian Ordinary Ship Register (NOR) under the name Achilles. From 2013, she was named FFS Achilles. The vessel was classified by Lloyd’s Register Group Ltd.

Figure 8: FFS Achilles. Photo: Farsund Fortøyningsselskap AS

1.8.2 Relevant certificates

FFS Achilles had valid trading and safe manning certificates issued by the Norwegian Maritime Authority. The vessel also had a valid class certificate issued by Lloyd’s Register.

1.8.3 Voith Schneider propulsion and steering system

A general description of the Voith Schneider (VS) propulsion and steering system is provided in Annex A, part 1, and a specific description for FFS Achilles is provided in Annex A, part 2.

According to the shipping company, FFS Achilles, like other vessels with VS propulsion in the bow section, had poor course stability characteristics. This was particularly pronounced when moving forward, while it was easier to keep her on course while going astern. Due to the weak course stability, the autopilot was normally used en route to or from towing assignments.

According to the shipping company, the autopilot would normally respond immediately when a change of course was initiated using the control stick. The exception to this rule was that it could take a little longer to respond if there was a strong current. When activated, the autopilot was connected to the VS units' mechanical control system using a clutch, and the steering wheel on the console would rotate in accordance with the 'command' from the autopilot. The rotation of the steering wheel thus acknowledged the change of course initiated and functioned as a form of 'rudder indicator'.

1.8.4 <u>Navigation equipment</u>

1.8.4.1 *Autopilot*

The vessel was equipped with an autopilot of the Simrad AP-50 type which was located in a console near the ceiling to port of the centre line, see Figure 3. The autopilot remained active until FFS Achilles ran aground. This unit did not store data.

The autopilot could be partly remotely controlled from a control stick located at the back of the console on the starboard side of the navigator position, see Figure 4. The remote control stick was rigged so that it worked as a switch that triggered a 1° change of course to the side to which the control stick was moved. When the control stick was operated, it made a distinct sound that marked a course change. To change the course by more than one degree, the movement had to be repeated for each degree by which one wanted to change the course.

See Annex A, part 2 for a description of how the autopilot system functioned. The clutch motor that drove the chain to the threaded rod on the rudder pitch control mechanism was replaced in autumn 2016. Otherwise, the system required only minimal servicing as the chain had to be cleaned and lubricated once a year.

1.8.4.2 *Chart plotter*

FFS Achilles had a Transas ECDIS 4000 chart plotter which was not officially approved. The Regulations of 5 September 2014 No. 1157 on navigation and navigational aids for ships and mobile offshore units apply to e.g. cargo ships with an overall length of 24 metres or more. The Regulations require that '*Up-to-date official nautical charts and nautical publications for the planned voyage shall be available on board, so that the positions can be plotted and monitored throughout the voyage.'* This means that up-to-date official paper charts were the 'approved' charts on board FFS Achilles.

1.8.4.3 *Radar*

During the voyage leading up to the grounding, the vessel's JRC radar was active, the display set to head-up and the range set to 0.5 nautical miles.

1.8.5 <u>The vessel's design – general information</u>

FFS Achilles' arrangement had not been altered from the time she was built until the day of the accident. The content of the class notation and annual inspections by Lloyd's Register, most recently six months before the accident, indicates that FFS Achilles satisfied Lloyd's Registers' applicable requirements in 1984 as regards design, dimensioning and equipment.

1.8.6 <u>Watertight compartments – bottom design</u>

FFS Achilles had watertight bulkheads at each end of the engine room at frames 10 and 49, see Figure 9 and Figure 10. The auxiliary engine room above the tank top and between the wing tanks from frame 10 to frame 18, the main engine room from frame 18 to frame 44 and the workshop/storeroom above the tank top/cofferdam from frame 44 to frame 49 was thus one continuous compartment. This compartment could be filled if a single instance of damage to the hull created an opening. Other watertight bulkheads were the afterpeak and forepeak bulkheads at frame 4 and frame 52, respectively.

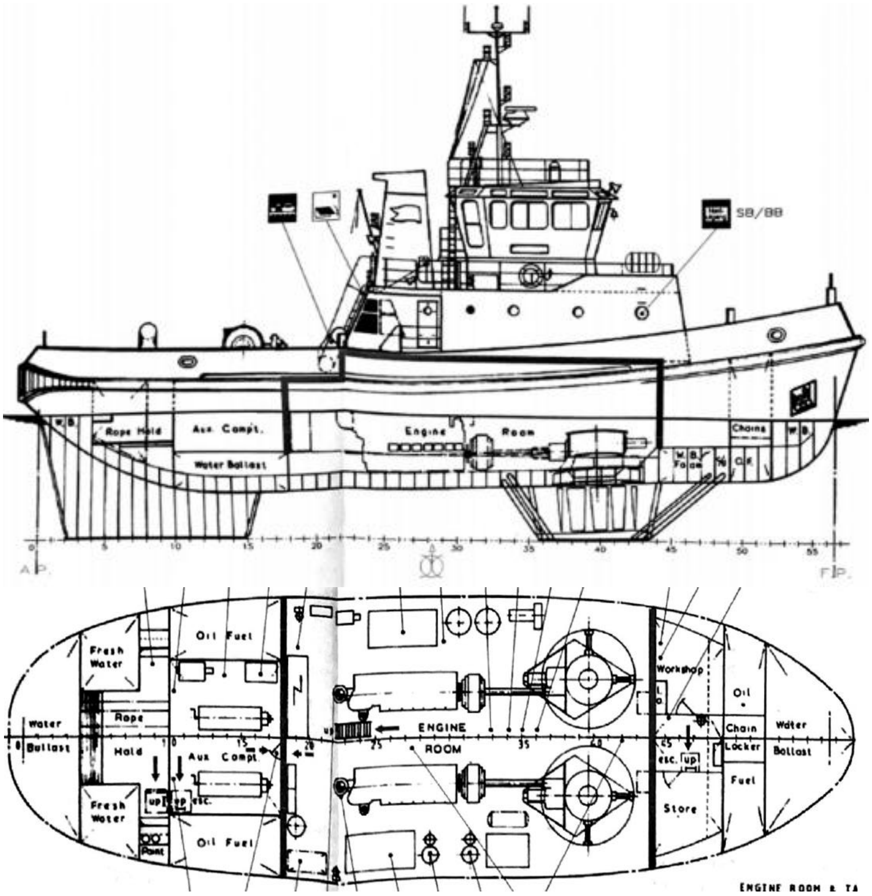


Figure 9: FFS Achilles – arrangement. Source: Farsund Fortøyningsselskap AS

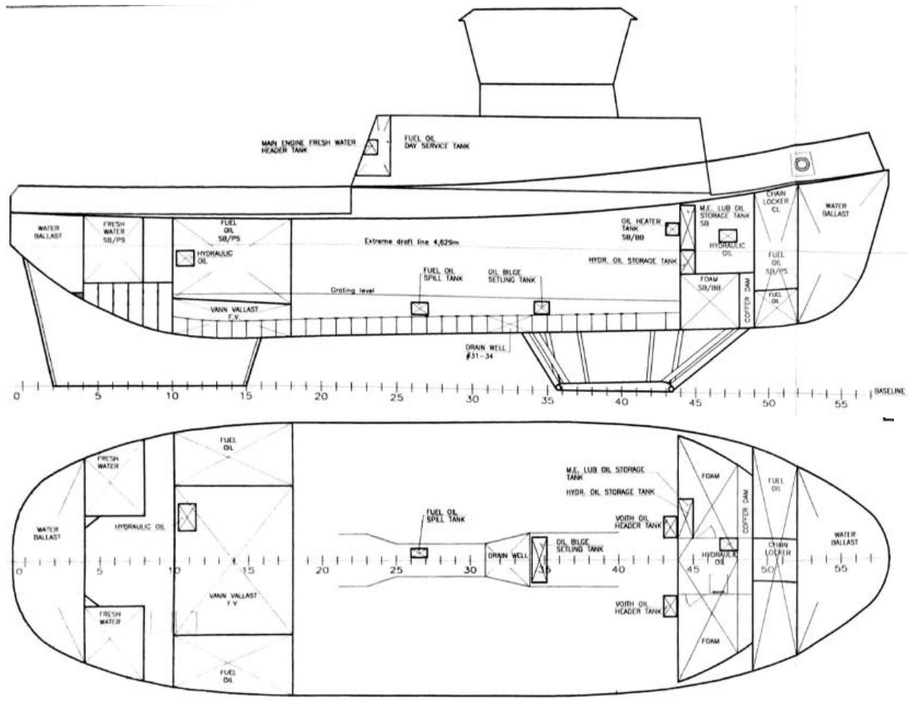


Figure 10: FFS Achilles – tank plan. Source: Farsund Fortøyningsselskap AS

FFS Achilles was designed with a single bottom in the main engine room between frames 18 and 44. The 'foot' of the propeller guard was fastened to the hull by ten struts, five along the forward edge and five along the rear edge. Figure 10 shows that the central forward strut was fastened to the hull in an area protected by a double bottom. The starboard and port forward inner struts were fastened to the hull at frame 44 and at the rear of the bottom tank. This attachment point was thus not actually protected by a double bottom. The other seven struts were attached to the hull in single-bottomed areas. The starboard rear inner strut, which broke off and tore a hole in the skin causing water to fill the vessel, was attached at frame 35.

Damen Shipyards in Gorinchem in the Netherlands has presented a Voith Schneider tugboat design that is comparable with FFS Achilles. The design has a double bottom between the peak bulkheads, except in the area around the propeller units, and a watertight transverse bulkhead approximately halfway along the propeller shafts. See Annex D for a more detailed description.

1.8.7 Bilge pumping arrangement

Two electric bilge pumps, each with a capacity of 130 m^3/hour, were located on the starboard side of the engine room. Common suction pipes to the bilge pumps had suction points at the back and front of the main engine room at frames 18 and 44, respectively. One auxiliary engine (electric generator), which was always running when the vessel was operating, had sufficient capacity to power one of the bilge pumps. Both the auxiliary engines would have to be running to run both bilge pumps. Both auxiliary engines were running when FFS Achilles sank.

For obvious reasons, it is not possible to perform a function test on the bilge pumps connected to the bilge lines unless the vessel has had an accident that involved ingress of water into the engine room. However, the bilge pumps were tested regularly as 'ballast pumps’, i.e. connected to a seawater intake for use as fire pumps or to supply the sprinkler system when these functions were tested.

Figure 11: Mud box on a bilge line with grate on the right. Photo: AIBN

The bilge line’s rear mud box was opened when the vessel was examined, see Figure 11. There were grates in the mud boxes intended to prevent debris from being sucked into the pumps. As the figure shows, the grate was largely covered in debris that would have reduced the flow and thereby the pumping capacity.

1.8.8 Other pump capacity

FFS Achilles had a FIFI (firefighting) system with two foam cannons mounted on each side at the rear of the wheelhouse roof. The system also comprised two deluge guns, one on top of each funnel. The deluge guns were supplied by two FIFI pumps, each with a capacity of 1,500 m^3/hour. The FIFI pumps were powered by the main engine via a gearbox fitted behind each main engine. When the pumps were running, they drew 650 hp from each main engine.

The FIFI pumps had their own seawater intake and could not be used for pumping water out of the vessel.

1.9 The shipping company

1.9.1 General information

FFS Achilles was owned by Farsund Fortøyningsselskap AS. At the time of the accident, the shipping company also had two other tugboats, a work boat, a barge and a pilot vessel, in addition to several smaller work boats with an overall length of less than 15 metres.

1.9.2 The shipping company’s procedures

The shipping company did not have written procedures for bridge manning and sailing in narrow channels after dark. The use of a dedicated lookout on the bridge was not practised.

The company did have a procedure for use of floodlights when sailing through Prestøysundet sound in the dark. This procedure was not put into writing, but the shipping company states that its content was emphasised when training the company's navigators and rating navigators for captain clearance.

When sailing northwards through Prestøysundet sound, the floodlight was to be turned on after passing Skotteflua beacon in order to find the red marker on Kong Sverre båen reef, which was particularly 'dark'. The procedure was to continue up the sound with the floodlight aimed forward to pick out the reflectors from the next three markers in the sound so that they could be identified. The next three markers were Søre Lamholmflua (green), Vestre Lamholmflua (red) and Nordre Lamholmflua (green), see Figure 2.

According to the navigator's statement, the floodlight was not turned on until the vessel was approaching Lamholmen islet, which is about 1,200 metres further up Prestøysundet sound than the location prescribed by the procedure. At a speed of 8.5 knots, it will take 4½ minutes to cover this distance.

1.10 Relevant rules and regulations

1.10.1 Requirements for watertight subdivision/double bottoms

If a vessel similar to FFS Achilles were to be built today to sail under the Norwegian flag, Regulations of 1 July 2014 No. 1072 on the construction of ships would apply. Section 4 of the Regulations state that for cargo ships of less than 500 gross tonnage engaged on foreign voyages (non-SOLAS ships), the requirements of a recognised classification society shall apply to the construction and maintenance of the hull, main and auxiliary engines etc. Norway as a flag state does not enforce other national requirements for watertight subdivision/double bottoms for this type of vessel.

It follows from SOLAS 1974 Regulation 4 that damage stability requirements apply to cargo ships with a length (L) of 80 metres or more. Damage stability requirements will also apply to chemical/oil tankers and ships defined as support vessels (for operations in safety zones around oil installations). Consequently, no damage stability requirements will normally apply to a tugboat of FFS Achilles' size.

DNV-GL Rules for classification, Ships, part 3 Hull, chapter 2, section 2 deals with requirements concerning watertight arrangement design. The minimum requirements for watertight bulkheads are one collision bulkhead, one aft peak bulkhead and one bulkhead at each end of the engine room. If the engine room is located at the rear of the vessel, it is acceptable for the aft peak bulkhead and the rear engine room bulkhead to be the same bulkhead. Based on the above, the minimum number of watertight bulkheads in a tugboat of the same type as FFS Achilles, built in accordance with DNV-GL's rules, will be four.

According to section 3 item 2.1.2 in DNV-GL's rules, requirements regarding double bottom and any requirements regarding the vessel's ability to withstand bottom damage in parts of the vessel not fitted with a double bottom will be assessed on a case-by-case basis for new tugboats of the same type as FFS Achilles.

1.10.2 Lookout requirements

The International Regulations for Preventing Collisions at Sea, 1972 (COLREG), were incorporated into Norwegian law in Regulations of 1 December 1975 No 5 for preventing collisions at sea (Rules of the Road at Sea). Chapter I of the Rules of the Road at Sea contains the international rules and Chapter II contains special rules for Norwegian inland waters.

The Rules of the Road at Sea Chapter I, Rule 5 Look-out, sets out the requirement that *'any vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.'*

National and international interpretations of Rule 5 mostly agree that what is meant by 'all available means' is that vessels should use radar, AIS, information from navigational warnings, communication with other vessels and the vessel traffic service centre (VTS), night vision equipment, etc.

Regulations of 27 April 1999 No 537 on watchkeeping on passenger ships and cargo ships (the Watchkeeping Regulations), which apply to apply to Norwegian passenger ships and cargo ships of 50 tons and upwards, also contain provisions on lookout. Appendix A to the Regulations, Part 3-1 states that 'a proper look-out shall be maintained at all times in compliance with rule 5 of the International Regulations for Preventing Collisions at Sea.' According to the appendix, the purpose of this is, among other things, 'fully appraising the situation and the risk of collision, stranding and other dangers to navigation'.

The appendix goes on to state that *'The duties of the look-out and helmsperson are separate and the helmsperson shall not be considered to be the look-out while steering, except in small ships where an unobstructed all-round view is provided at the steering position and there is no impairment of night vision or other impediment to the keeping of a proper look-out. The officer in charge of the navigational watch may be the sole look-out in daylight subject to certain conditions.'*

1.11 Medical matters

The police administered a breathalyser test for alcohol on the navigator at Flekkefjord hospital. The result of the test was negative.

2. ANALYSIS

2.1 Introduction

The sequence of events and the vessel's changes of course before the grounding are discussed in Chapter 2.2. It emerges from this that the navigator's statement does not agree with the other factual information in the case. The AIBN has not been able to explain why the autopilot did not respond to the navigator's attempt at steering. Regardless of this, the AIBN's further analysis is aimed at explaining why the margins were so small that the vessel ran aground and why the vessel sank.

2.2 Sequence of events

2.2.1 The vessel's change of course before the grounding

The navigator has stated that 31 seconds before the grounding, the autopilot did not respond when he initiated a change of course of a few degrees to port using a control stick to remotely control the autopilot. He therefore decided to deactivate the autopilot to switch to manual control, but the vessel ran aground before he could do so.

The autopilot did not store data and the AIBN’s investigation did not find any faults or defects in the mechanical control system between the wheelhouse and the propeller units. Nor did the shipping company find any faults or defects in this control system. According to Voith Turbo GmbH & Co, it is unlikely that the damage to the propeller units could have occurred before the grounding. Therefore, the AIBN is unable to explain why the navigator felt that the autopilot did not respond.

The AIBN’s investigations and confirmations from Voith Turbo GmbH & Co indicate that the vessel ran aground with 65% driving pitch and 0% rudder pitch. Based on the navigator’s statement that he was unable to change the vessel’s course for the last 31 seconds, the vessel would have had 0% rudder pitch throughout this period (no control effect on the propellers). However, the AIS signals show that the vessel's course changed by six degrees to port during the final 31 seconds. This does not agree with the navigator’s impression that the vessel may have turned to starboard just before it ran aground.

2.2.2 Sea conditions – currents

Based on water level data showing that high tide had just occurred in the waters where the vessel ran aground, it is reasonable to assume that the outgoing tidal current would be starting, and the outgoing tidal current in Prestøysundet sound would be going in a south-easterly direction. This means that FFS Achilles would have been moving against the current in the sound. However, this does not tally with the vessel’s drift path after the grounding. The overall drift path was north-westerly from the position where the vessel ran aground to the position where she sank.

The wind direction in Prestøysundet sound was probably not significantly different from the direction measured at Lista and Lindesnes lighthouse. Based on this, the wind would have been more or less at a right angle to the drift path. Consequently, the primary cause of the north-westerly drift was the current. In the AIBN’s opinion, this makes it unlikely that the vessel was sailing against the current in Prestøysundet sound. Given the north-westerly drift, it is probable that the vessel was sailing with the current, which was slow, before the grounding.

2.2.3 Change of course initiated on board the vessel

If the wind (W) from the south-west and possibly the direction of the current (S) towards the port side of the vessel were the only factors that influenced the vessel's course during the final part of her voyage, i.e. if no change of course had been actively initiated on board, the relationship between HEADING and COG would have been as shown under a) in Figure 12. This would be the most probable relationship between HEADING and COG assuming that the navigator’s statement is correct.

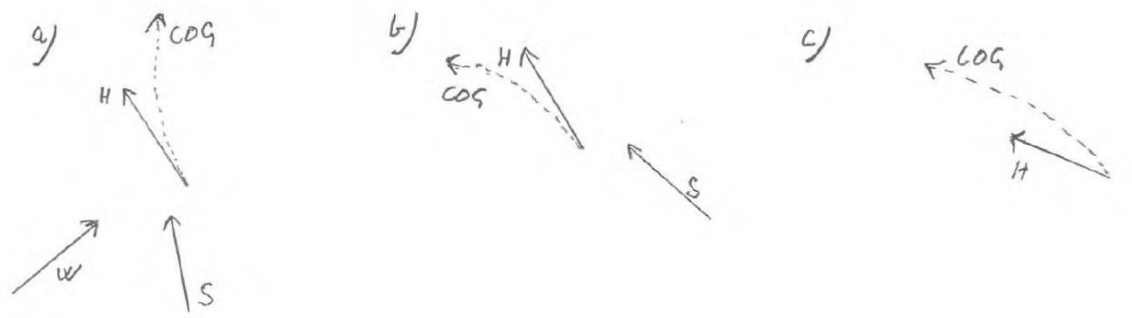


Figure 12: Relationships between HEADING and COG just before the grounding.

If no change of course was initiated on board, the direction of the current was towards the port side and the current was a stronger influence on the course than the wind, the relationship between HEADING and COG would have been as shown under b) in figure 12.

However, according to the vessel's AIS information, the relationship between HEADING and COG was as shown under c) in Figure 12. COG turned west, the vessel turned to port into the wind, and HEADING was typically at the windward side of COG through Prestøysundet sound until the vessel ran aground.

Taking into account the prevailing sea conditions at the time of the accident, south-westerly wind and a slow current in the same direction as the vessel was travelling, it is the AIBN's opinion that the latter relationship between HEADING and COG could only occur if the changes of course were initiated on board the vessel. This will thus also apply to the changes of course during the final 31 seconds of the vessel's voyage. The changes of course to port were small. The fact that the propeller units had 0% rudder pitch at the moment of impact could indicate that the changes of course were initiated gradually by a few degrees at a time.

The AIBN assumes that a modest current in the direction of travel could affect the autopilot, which would take longer to respond in strong current according to the shipping company. The AIBN therefore assumes that before the accident, the navigator experienced rapid response from the autopilot to the changes of course he initiated. Consequently, it should not take long to detect a failure to respond such as that which the navigator has stated that he experienced before the grounding. The AIBN assumes that the vessel was approx. 130 metres from the reef, which equates to approx. 31 seconds of sailing, when the navigator found the autopilot to be unresponsive.

2.3 Operational factors

2.3.1 The navigator's handling of the situation

According to the navigator's statement, the floodlight was not turned on until the vessel was approaching Lamholmen islet. This is approx. 1,200 metres, corresponding to approx. 4½ minutes, further up Prestøysundet sound than prescribed by the shipping company's unwritten procedure (ref. Chapter 1.9.2).

On the evening of the accident, the course was set straight for Kong Sverre båen reef after the vessel had passed Skotteflua beacon, see Chapter 1.6.2. The course corrections, which began at a distance of 119 metres from the marker, had relatively high rate of turn (ROT) values. The course corrections to round the red marker correctly were thus relatively sudden, but not so extreme that it can be described as an 'evasive manoeuvre'. The fact that the course was set directly towards Kong Sverre båen reef could have been because the floodlight was not turned on and there was therefore no reflection from the dark marker by which to navigate.

The navigator believed that the vessel passed the red marker at Vestre Lamholmflua at a distance of 10 metres, but also expressed uncertainty about this. According to AIS, however, the distance was 75 metres (see Chapter 1.6.2). FFS Achilles was abreast of the marker 31 seconds before it ran aground, and was then 130 metres away from the reef at Nordre Lamholmflua.

The navigator's uncertainty about the exact position of the vessel for the remaining 31 seconds of its voyage may have influenced his actions when he found that the autopilot was not responding. He spent most of the time at his disposal on making the decision to switch from autopilot to manual control.

2.3.2 Lookout requirements

Appendix A to the Watchkeeping Regulations (see Chapter 1.10.2) states that for FFS Achilles, which must be considered '*a small ship where an unobstructed all-round view is provided at the steering position*', the helmsman and the lookout could in principle be one and the same person. The officer in charge of the navigational watch could also be alone on the bridge in daylight subject to certain conditions.

However, the voyage leading up to the grounding took place in the dark, and the floodlight was on during the final stretch through Prestøysundet sound. Generally speaking, it was dark, which means that the officer in charge of the navigational watch could not be the sole lookout, and particularly not when he was also the helmsman steering the vessel.

The AIBN is of the opinion that the Watchkeeping Regulations prescribe that FFS Achilles should have had a separate dedicated lookout on the bridge after dark on the day of the accident. The AIBN also believes that a dedicated person monitoring the voyage from the wheelhouse in addition to the navigator could have made a difference to the chain of events. It must be assumed that two persons would have been better able to judge the vessel's position in relation to the red marker at Vestre Lamholmflua and thus the distance to the reef. An increased awareness of the exact position of the vessel would have made it more likely that purposeful action to prevent the vessel from grounding would have been taken.

The AIBN submits a safety recommendation to the shipping company on this point.

2.3.3 Navigation based on unofficial charts

The navigator was steering FFS Achilles with the aid of unofficial charts/plotter. Up-to-date paper charts were the official ('approved') charts on board the tugboat, but they were not used in practice. However, the AIBN has no basis for claiming that this had any bearing on the chain of events.

2.4 The sequence of events of the sinking

The damage that occurred when the boat ran aground and that resulted in ingress of water is described in Chapter 1.4. A hole in the skin measuring 250 x 300 mm was created at frame 35, i.e. slightly forward of midship under the engine room. There were watertight bulkheads at frames 10 and 49, see Figure 9 and Figure 10. This made 65% of the vessel's length, with most of the vessel's intact buoyancy, available to be filled. The water ingress, Q, can be estimated using the following expression based on Bernoulli's equation:

$Q = CA\sqrt{2g(H1 - H2)}$, with:
C being the friction coefficient, which can be assumed to be 0.6 for openings with sharp edges
A being the area of the hole in the skin, 0.075 m^2
g being the gravitational acceleration, 9.81 m/s^2
H1 being the depth of the hole below water level outside the hull, 2.76 m (draught to the lower edge of the foil/skeg was approx. 4.60 m)
H2 being the depth of the hole below water level inside the hull

The ingress of water was highest just after the skin was torn (H2 equalled 0). As water collected in the hull (H2 increased), the water ingress decreased as a result of the water already in the hull creating back pressure. This is reflected in the expression above. However, the vessel's draught, H1, also increased as a result of the increasing quantity of water.

When the skin was punctured, 330 litres of water per second flowed in through the hole. With H2 equalling 0.5 m and 1.5 m, the flow was 300 and 220 l/s, respectively. In the above-mentioned estimates, H1 remains the same (2.76 m), which means that the actual flow has been greater than the estimates.

The vessel's two bilge pumps each had a theoretical capacity of 130 m^3/hour, which gives a total of 72 litres per second. The theoretical capacity will to a certain extent have been reduced by the head height to the overboard outlet, resistance in bilge lines and debris in the mud boxes on the bilge lines. If the levels of H1 and H2 had differed by up to 11 cm, the inflow of water through the hole would have been reduced to a level where the bilge pumps could have kept up with the inflow.

However, rough calculations that the AIBN has carried out with an inflow quantity to a level 11 cm below the external water line before the damage occurred show that the deck midships would be well below water at this stage. As the vessel listed, water also entered through the open door from the deck to the interior of the vessel and down into the engine room at this point.

Based on the above, the bilge pumps could never have kept up with the inflow of water through the damage and the residual buoyancy aft of frame 10 and forward of frame 49 was insufficient to keep the vessel afloat.

2.5 The drainage system

FFS Achilles had a relatively high quantity of debris in the rear mud box on the bilge line. This will have reduced the pumping capacity to a certain extent. However, this did not have any bearing on the sequence of events, as the maximum theoretical pumping capacity was insufficient in relation to the scope of the damage.

The AIBN would nevertheless like to point out that, for obvious reasons, the functioning of drainage systems is not tested regularly because that would require water in the engine room. This applies to the bilge lines with pertaining mud boxes in particular. The investigation shows how important it is to keep the engine room in good order to ensure that the drainage system functions as well as possible should a critical situation arise. Debris should be removed so that it cannot be drawn towards the suction points and clog the mud boxes on the bilge lines. It is particularly important to keep the space below the engine room floor free of debris.

FFS Achilles had a considerable total pumping capacity. The FIFI pumps, each with a capacity of 1,500 m^3/hour, and the bilge pumps had a combined capacity of 3,260 m^3/hour. Only 260 m^3/hour of this capacity could be used to pump water out of the vessel.

If it had been possible to use the FIFI pumps for this purpose, the vessel would have had a theoretical capacity of 905 l/second. The maximum ingress of water through the damage that occurred at the grounding has been calculated at 330 l/second. In theory, one of the FIFI pumps with a capacity of 416 l/second alone could have kept the vessel afloat. However, the FIFI pumps were dedicated to firefighting and could only suck in seawater from outside the hull through special seawater intakes.

2.6 Design requirements for tugboats of less than 500 gross tonnage

With its single bottom and long midship compartment between the transverse watertight bulkheads, FFS Achilles was vulnerable to the type of damage that can occur as a result of grounding. The propeller guard design, with nine out of ten struts being attached to areas with a single bottom, made the vessel even more vulnerable.

When FFS Achilles ran aground, one of the propeller guard struts tore a 250 mm x 300 mm hole in the single bottom under the engine room. The vessel’s bilge pump capacity was insufficient to compensate for the water ingress through the hole, and the reserve buoyancy forward and aft of the engine room bulkheads was not enough to keep the vessel afloat.

For a new tugboat of the same type as FFS Achilles, the rules of a recognised classification society would be applied as regards requirements for a double bottom in the engine room and for the ability to withstand bottom damage (performing damage stability calculations) in areas without a double bottom. In principle, both requirements apply under DNV-GL’s rules, but as such vessels are not regulated by SOLAS, the requirements are not absolute, but subject to case-by-case assessment. Based on the above, a new Norwegian vessel similar to FFS Achilles can be built with the same watertight subdivision and single bottom in the engine room, as was FFS Achilles’ arrangement.

It is not unnatural for a grounding at the speed at which FFS Achilles ran aground to result in extensive damage that caused the vessel to sink. Nevertheless, the investigation shows that some design modifications would have made the damage that FFS Achilles suffered survivable. In the AIBN’s opinion, the Damen VTD TUG 3212 design (see Annex D) would probably have withstood corresponding damage and remained afloat.

3. CONCLUSION

3.1 Sequence of events

a) Considering the relevant weather and current conditions, the navigator's statement does not tally with the relationship between HEADING and COG according to the AIS signals.

b) FFS Achilles was heading directly towards Kong Sverre båen reef for 4½ minutes before the grounding. Course corrections were made when the distance between the vessel and the marker on the reef was 119 metres.

c) The floodlight was not turned on until the vessel was about 1,200 metres further up Prestøysundet sound than the location prescribed by the company's unwritten procedure. This could have caused the navigator to be uncertain about the vessel's exact position.

d) According to the navigator, the autopilot suddenly failed to respond when the vessel was approx. 130 metres from the reef, which corresponds to 31 seconds. The navigator spent most of these 31 seconds making the decision to switch from autopilot to manual control.

e) According to the Watchkeeping Regulations, FFS Achilles should have had a dedicated lookout in addition to the navigator when the accident happened. A lookout would probably have helped to improve awareness of the vessel's exact position and therefore also of the distance to the reef.

f) The investigation has not found any faults or defects in the mechanical control system, including the mechanical part of the autopilot system.

3.2 The sequence of events of the sinking

a) The single bottom in the long midship compartment between the transverse watertight bulkheads made FFS Achilles vulnerable to the type of damage that can occur as a result of grounding. The fact that nine out of ten struts were attached to areas with a single bottom made the vessel even more vulnerable.

b) FFS Achilles sank because one of the propeller guard struts tore open the single bottom and the inflow of water through the hole cause by the grounding exceeded the bilge pumps' capacity. The buoyancy of intact compartments forward and aft of the engine room was insufficient to keep the vessel afloat.

c) FFS Achilles had a relatively high quantity of debris in the rear mud box on the bilge line. This will have reduced the pumping capacity to a certain extent. However, this did not have any bearing on the sequence of events, as the maximum theoretical pumping capacity was insufficient in relation to the scope of the damage.

d) A tugboat of the same type as FFS Achilles, which is not regulated by SOLAS, can still be built with a single bottom in the engine room today because the applicable requirements (DNV-GL's rules) are not absolute for non-SOLAS ships.

4. SAFETY RECOMMENDATIONS

The investigation has identified one area in which the Accident Investigation Board Norway deems it necessary to submit a safety recommendation for the purpose of improving safety at sea.[2]

Safety recommendation MARINE No 2019/04T

The investigation into the foundering of FFS Achilles on 3 March 2017 has found that the shipping company had no written procedures for bridge manning and sailing in narrow channels after dark. The AIBN is of the opinion that a lookout in accordance with the applicable regulations would have increased awareness of the vessel's exact position and thus increased the probability of avoiding the accident.

The Accident Investigation Board Norway recommends that Farsund Fortøyningsselskap AS implement written procedures for bridge manning and sailing in narrow channels after dark, including the Watchkeeping Regulations' provisions on the use of lookouts, in the safety management system for their vessels.

Accident Investigation Board Norway

Lillestrøm, 21 October 2019

[2] The investigation report is submitted to the Ministry of Trade, Industry and Fisheries, which will take the necessary steps to ensure that due consideration is given to the safety recommendations.

DETAILS OF THE VESSEL AND THE ACCIDENT

Vessel	
Name	FFS Achilles
Country of registration / register	Norway/NOR
Home port	Farsund
Call sign	3YAW
IMO no	8224523
Type	Tugboat
Building yard	Argibay Shipyard, Alverca, Portugal
Build number	157
Build year	1984
Owner and operator	Farsund Fortøyningsselskap AS
Construction material	Steel
Gross tonnage	285
Maximum length	30.21 metres
Length (L)	Approx. 27.2 metres
Breadth, moulded	9.20 metres
Depth, moulded	3.80 metres
Summer draught	4.629 m (to the lower edge of the skeg and propeller guard)
Frame spacing	500 mm
Engine power	2,640 BHP
Other relevant information	2 x Voith Schneider propellers in the foreship
The voyage	
Port of departure	Kvina Verft, Fedafjorden
Destination port	Farsund
Type of voyage	Return after completed assistance operation
Number people on board	3
Information about the accident	
Date and time	3 March 2017 at 19:56:15
Type of accident	Grounding/foundering
Location/position where the accident occurred	Nordre Lamholmflua in the approach to Farsund
Number of persons dead/injured	No dead, two injured
Damage to the vessel and the environment	The vessel sank, no environmental damage
Ship operation	Transit (no towing)
At what point of the voyage was the vessel	Approx. 6 minutes remaining to the destination in Farsund

ANNEXES

Annex A: Description of the Voith Schneider system on board FFS Achilles

Annex B: Examination of the vessel after the accident

Annex C: The raising of FFS Achilles

Annex D: New design equivalent to FFS Achilles

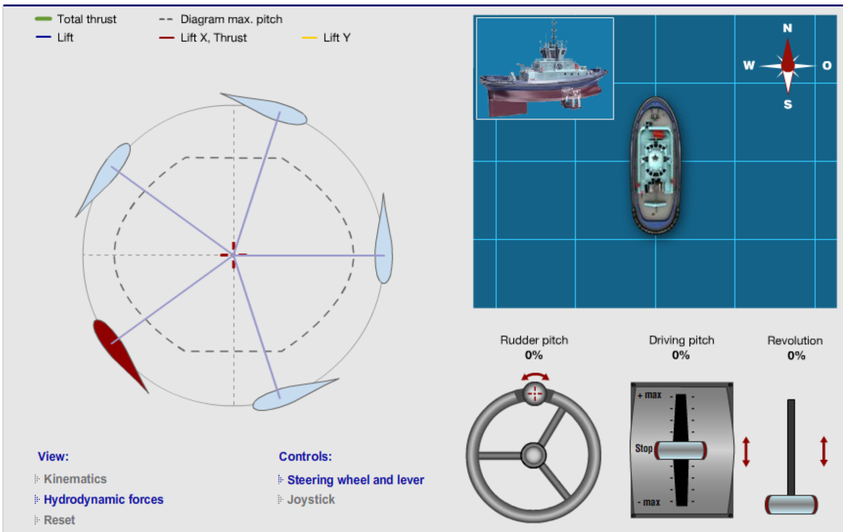
ANNEX A: DESCRIPTION OF THE VOITH SCHNEIDER SYSTEM ON BOARD FFS ACHILLES

1. General information about the Voith Schneider propulsion and steering system

FFS Achilles was equipped with a Voith Schneider (VS) propulsion and steering system where the main engines powered one propeller unit each via axles, see Figure 9. Five vertical propeller blades on each unit were attached to rotating discs that were flush with the bottom of the vessel. The discs rotated at a speed proportional to the main engine speed. The VS systems are known for being able to change thrust direction and magnitude very rapidly. Tugboats with VS systems are known for being highly manoeuvrable, which is a particularly valuable characteristic in tugboats when assisting big vessels in narrow and difficult waters.

Hydrodynamic lift, and thus thrust, is achieved by varying the pitch of the rotating propeller blades. The thrust direction and magnitude for a given engine speed, and thus a given rotation speed for the propeller blades, are regulated by two mechanisms – rudder pitch and driving pitch.

Figure 13 shows different configurations of rudder and driving pitch for one propeller unit. The drawings also indicate the magnitude and direction of the hydrodynamic forces that act on the vertical propeller blades, as well as the resulting thrust.



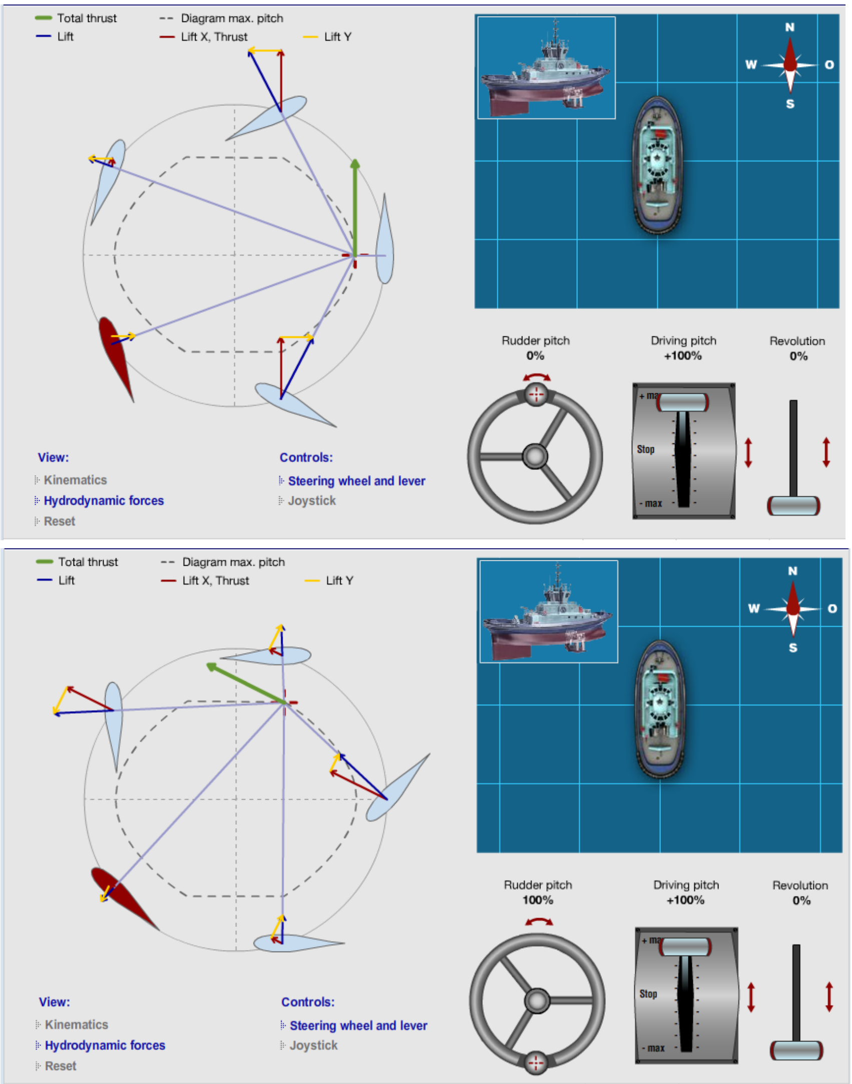


Figure 13: Voith Schneider propellers, top drawing 0% rudder and driving pitch, middle drawing 0% rudder and 100% driving pitch (forward), bottom drawing 100% rudder (to port) and driving pitch (forward). Source: Voith

2. Operating rudder and driving pitch on board FFS Achilles

On board FFS Achilles, the rudder and driving pitch were operated mechanically via rods from the steering console in the wheelhouse, down through the superstructure to the propeller units.

Rudder pitch:

When the steering wheel on the steering console was turned, see Figure 3, that rotated a vertical threaded rod inside the console, see Figure 14. One end of an angled lever moved up or down the threaded rod depending on which way the steering wheel was turned. The other end pushed or pulled a horizontal rod going aft below the wheelhouse floor, see Figure 16. Longitudinal movement of the horizontal rod was transferred as rotation of a vertical rod that went down into the engine room, see Figures 17 and 18. Below deck in the engine room, the rudder pitch rod was attached to separate rods for each propeller unit. This engaged the rudder pitch, and when the steering wheel in the wheelhouse was turned, that caused the same rotation (rudder pitch) on both propeller units. See Figure 24 and Figure 25, which show two grey vertical rods on top of each unit. One of them is the rudder pitch rod, the other one is the driving pitch rod.

Driving pitch:

The driving pitch to the starboard and port propellers could be operated independently or with the levers connected on the wheelhouse steering console, see Figure 3. When the levers were moved, that rotated longitudinal horizontal axles inside the console. The axles transferred this rotation to longitudinal pushes or pulls on the horizontal driving pitch rods, see Figure 14 and Figure 15. From there, the driving pitch rods followed the same path as the rudder pitch rod to the engine room. Below deck in the engine room, the driving pitch rods went to the starboard and port propeller units, respectively, descending vertically down to the top of them, see Figure 24 and Figure 25.

Autopilot:

Figure 14 and Figure 15 show a cogwheel at the end of the threaded rod from the wheel on the steering console. A chain wraps around the cogwheel, and this chain runs forward. There was an electromotor with a clutch at the forward end of the chain. When the autopilot was activated, this also activated the clutch to the motor so that the motor could rotate the threaded rod and thus change the rudder pitch. While the autopilot was active, it or the control stick sent impulses to the motor, which then made the necessary movement of the chain around the cogwheel on the threaded rod. Rotation of the threaded rod caused a change in rudder pitch that produced the desired change of course.

Figure 14: Inside the wheelhouse steering console (front). Vertical threaded rod from the wheel on the steering console at the top of the photo. Three vertical rods going backwards (to the left). Nearest the camera: rod for starboard driving pitch, in the middle for rudder pitch and furthest away for port driving pitch. Photo: AIBN

Figure 15: Under the wheelhouse steering console (back). Horizontal rods going aft (to the left). Nearest the camera we see the rod for starboard driving pitch, rudder pitch in the middle and port driving pitch furthest away. Photo: AIBN

Figure 16: Longitudinal movement transfer via the three horizontal rods to rotation in vertical rods. Rudder pitch in the middle. Photo: AIBN

Figure 17: Top of trunk on the bridge deck through which the rods pass through the superstructure down to the engine room. Photo: AIBN

Figure 18: The three pitch rods passing vertically through the trunk to the engine room. Photo: AIBN

ANNEX B: EXAMINATION OF THE VESSEL AFTER THE ACCIDENT

The AIBN reviewed the vessel’s propulsion and steering system together with the general manager of Farsund Fortøyningsselskap AS, who knew the vessel very well. The AIBN also conducted independent investigations. No visible damage or nonconformities were found in the mechanical control system from the wheelhouse through the superstructure down to the propeller units. Nor were there any visible damage or nonconformities in the mechanical part of the autopilot system.

Before examining the vessel, the AIBN had been in contact with the supplier of the Simrad AP-50 autopilot to clarify whether vital data from before the grounding had been stored in the unit. The autopilot in question did not store data.

The situation in the wheelhouse after the vessel had been raised was as shown in Figure 3. The navigator’s seat was positioned with the backrest to the rear, which does not agree with the navigator's statement.

Damage to the vessel could have occurred:

- on impact when the vessel ran aground

- when the vessel sank and hit the seabed

- during the raising operation when the vessel was lifted from the seabed and placed on the barge. The vessel was subject to a sudden jolt when she ‘fell’ as a result of the forward chain sling slipping forward.

- alternatively, before the vessel ran aground

Damage of relevance to the sequence of events was mainly observable in the foreship – on the Voith-Schneider propellers, the propeller guard and the hull in the immediate vicinity of the propellers and propeller guard.

The following observations were made after FFS Achilles had been raised and placed on the barge:

1. External damage and observations:

- The front of the foil (the ‘foot’ below the propellers) was damaged on the starboard side. It was obvious that this point had hit the reef.

- The forward and rear central struts that attached the foil to the hull had been torn off at the point of attachment to the foil. In addition, the rear central strut had cracks and was bent backwards approximately halfway between the hull and foil.

- The forward starboard strut had broken off at the point of attachment to the foil.

- The rear inner strut on the starboard side had broken off approx. 20 mm above the inside of the shell plate. The torn strut had moved downward in a way that tore open the shell plate and left a hole measuring approx. 250 x 300 mm. This hole opened the hull into the engine room.

- Circular scratches were found in the surface of the foil beneath the starboard propeller. The diameter of the scratches corresponded to that of the propeller.

- One of the blades of the starboard propeller was bent and turned 180 degrees on the vertical axis (the end of the blade was facing the opposite way to the other blades on the propeller). A white gasket inside the flange attaching the blade had been pushed out (down) slightly and become visible.

- The rotating disc of the starboard propeller had been pushed out (down) slightly and was no longer flush with the skin of the hull.

- There was evident buckling of the skin in the area where the forward lifting chain had been in contact with the hull when the vessel was raised. The chain formed a sling around the hull and was threaded between the forward inner struts and the forward centre strut of the foil.

Figure 19: Damage to the starboard forward edge of the 'foot', starboard strut knocked off and bent/twisted propeller blade. Photo: AIBN

Figure 20: Forward centre strut torn off at the foil. Photo: AIBN

Figure 21: Rear centre strut torn off at the foil, cracked/bent halfway up the length of the strut. Photo: AIBN

Figure 22: The rear inner strut on the starboard side had torn open the skin of the hull. Photo: AIBN

Figure 23: The blade attachment and rotating disk on the starboard side were pushed down. Scratches left by the propeller blades in the surface of the foil. Photo: AIBN

<u>2. The position of the propeller blades – direction of thrust</u>

- Seen from above, the starboard propeller unit normally rotated clockwise and the port unit anticlockwise.

- The blades on the port unit were in the neutral position, i.e. not producing thrust in any direction.

- Except for the bent blade that had turned in the opposite direction to the other ones, the blades on the starboard unit were in a position that would have produced forward thrust.

<u>3. Internal damage/observations – the propeller units</u>

Port propeller unit:

- The glass cover on top of the propeller unit was cracked/broken.

- The point of the indicator was bent, and there was no clearance between the indicator point and the glass cover.

- The indicator was positioned in the centre of its area of movement.

- No oil could be observed in the propeller unit.

Figure 24: Port propeller unit. Photo: AIBN

Starboard propeller unit:

- The indicator was positioned along the transverse axis to port (along the 0° axis and 65% to port). This indicates 0% rudder pitch and 65% driving pitch.
- The propeller unit had a visible oil level.

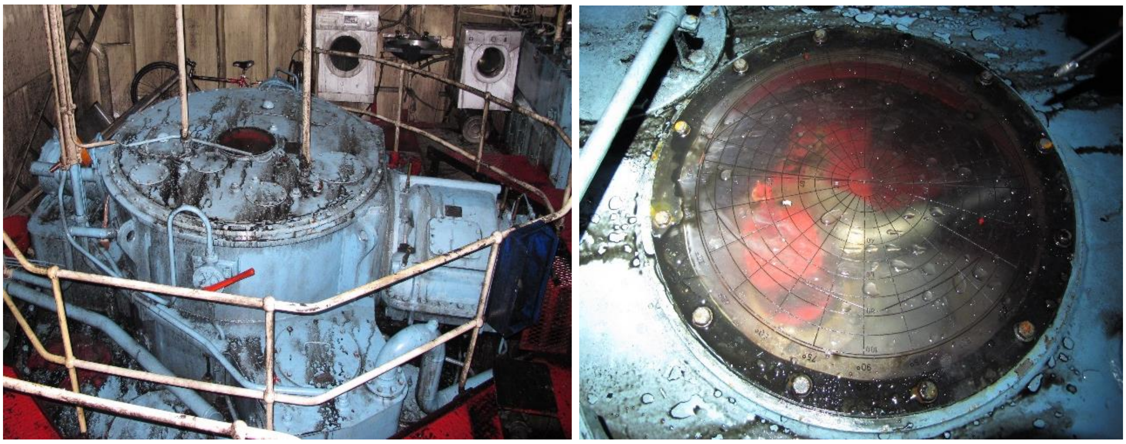


Figure 25: Starboard propeller unit. Photo: AIBN

ANNEX C: THE RAISING OF FFS ACHILLES

The tug sank with approx. 21 m^3 of fuel oil in its tanks. It had approx. 6.5 m^3 of lube oil, approx. 5 m^3 of which were in the propeller units. In addition, there were approx. 15 m^3 of firefighting foam in separate tanks and 300 litres in a hydraulic oil tank. The Norwegian Coastal Administration demanded that FFS Achilles be raised because of the risk of pollution.

The crane vessel Uglen, which belonged to Ugland Shipping AS, raised FFS Achilles on 16 March 2017. Uglen has a maximum lifting capacity of 600 tonnes divided between two main hooks with separate mantles. The lifting height for the two main hooks is 60 metres.

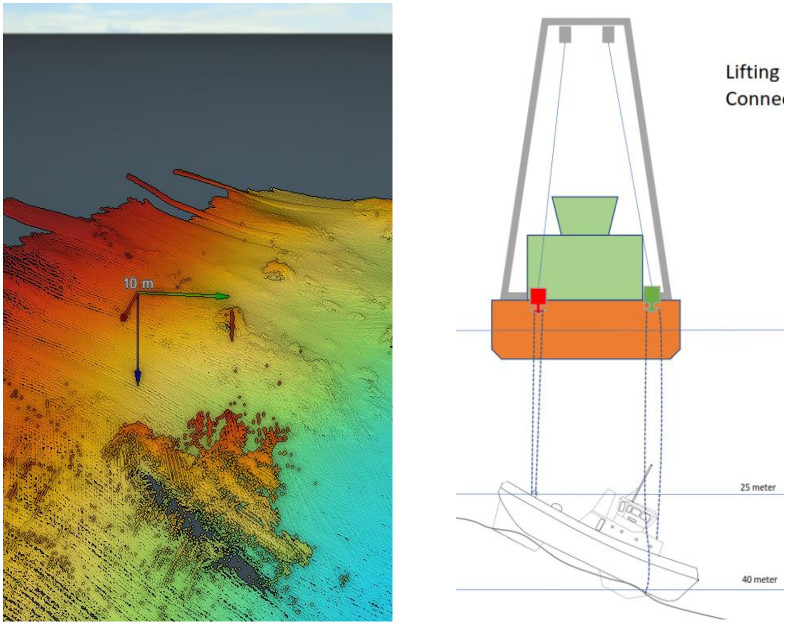


Figure 26: Multibeam echosound image of the vessel and schematic drawing of the raising operation. Source: FFS AS

FFS Achilles was lying at a depth of 25–40 metres on a slope as shown in Figure 26. In addition, the vessel was lying at a ‘list’ of approx. 30° to port. The forward chain sling was placed under the foreship between the struts in front of the propellers, while the aft sling was passed under the towing eye on the rear deck. The forward and aft chain sling consisted of 90 metres and 65 metres, respectively, of 76-mm chain hooked onto Uglen's main hooks.

Figure 27: FFS Achilles was raised on 16 March 2017. Photo: AIBN

The ‘list’ was corrected by trying to lift the aft end of the vessel first before lifting the foreship in order to lift the vessel out of the sea in a horizontal position. The tugboat weighed approx. 450 tonnes in air, and after being lifted out of the sea, she was placed on the deck of the barge FFS Ponton 6 and secured. The barge, which has a loading capacity of 2,300 tonnes, was then towed to the quay in Farsund where the AIBN later examined the vessel.

During the raising operation, the forward chain sling suddenly slipped forward with the result that the foreship of FFS Achilles ‘fell down’ with a jolt.

In Easter 2017, the barge was towed to Frederikshavn to deliver FFS Achilles to a yard to be broken up.

ANNEX D: NEW DESIGN EQUIVALENT TO FFS ACHILLES

Damen Shipyards in Gorinchem in the Netherlands has presented a Voith Schneider tugboat design that is comparable with FFS Achilles. This design, Damen VTD TUG 3212, is shown in Figure 28. Its overall length, breadth and moulded depth are 32.63 metres, 12.63 metres and 4.65 metres, respectively. This design is somewhat larger than FFS Achilles, but still has less than 500 gross tonnage.

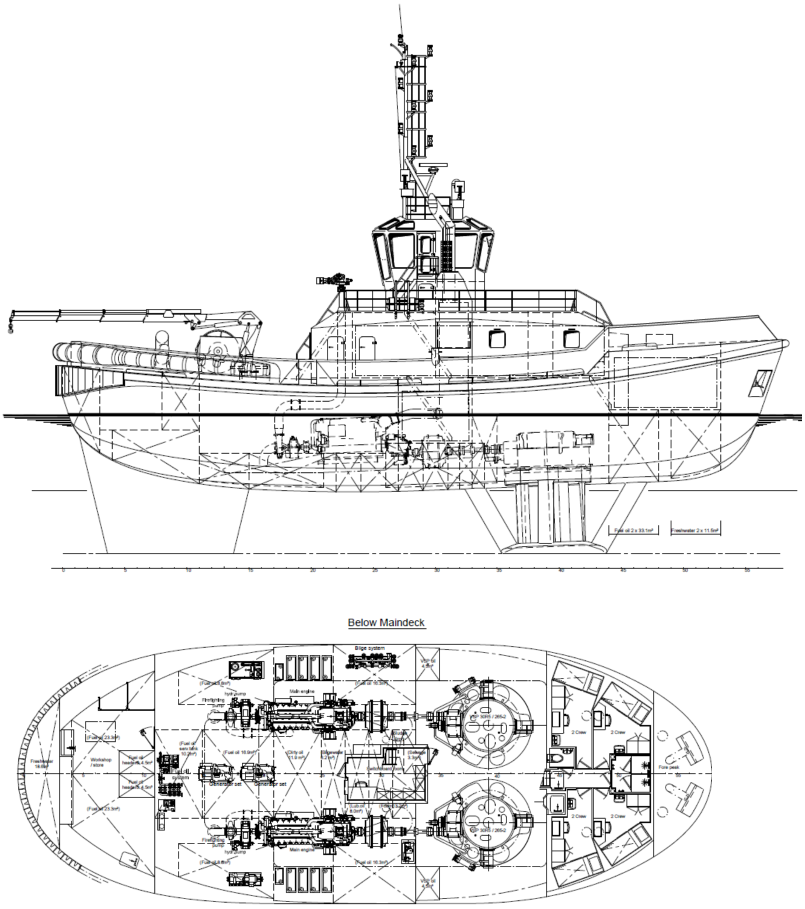


Figure 28: Damen VTD TUG 3212. Source: Damen Shipyards

As the figure shows, the design has a double bottom between the peak bulkheads, except in the area around the propeller units. According to Damen Shipyards, a double-bottom design is not possible in the area around the propeller units, as they are surrounded by sturdy transverse and longitudinal girders that can only be accessed from above.

The propeller guard struts are all attached to parts of the hull where there is a double bottom. Bottom damage caused by impact load on the struts, as was the case with FFS Achilles, will therefore in theory only cause the bottom tank(s) adjoining the point of damage to fill up with water.

In addition, the Damen VTD TUG 3212 design has a watertight transverse bulkhead approximately halfway along the propeller shafts, see Figure 28. The bulkhead thus separates the single-bottomed propeller room from the rest of the engine room. According to Damen Shipyards, the vessel will float with positive stability if the propeller room were to fill up with water. The design satisfies

DNV-GL’s rules regarding the vessel's ability to withstand bottom damage in areas not protected with a double bottom, see Chapter 1.10.1.

However, Damen Shipyards state that the classification societies do not require a double bottom arrangement as long as the vessel has less than 500 gross tonnage. Some flag states, on the other hand, do require smaller vessels to meet the requirements stipulated for vessels with a gross tonnage of 500 or more.