April 18, 2024 MIR-24-11

# Loss of Propulsion aboard Containership *Maunalei*

On August 11, 2022, about 1834 local time, the containership *Maunalei* was transiting the North Pacific Ocean, about 245 miles northwest of the entrance to the Columbia River, en route to Portland, Oregon, when the crew intentionally shut down the main engine due to problems in the controllable pitch propeller system, resulting in a loss of propulsion.[1] The vessel's controllable pitch propeller system may have lost up to 1,632 gallons of hydraulic oil. There were no injuries reported. Damage to the vessel was estimated at $3.03 million.


**Figure 1.** *Maunalei* underway before the casualty. (Source: Matson)

[1] (a) In this report, all times are Pacific daylight time, and all miles are nautical miles (1.15 statute miles). (b) Visit ntsb.gov to find additional information in the public docket for this NTSB investigation (case no. DCA22FM039). Use the CAROL Query to search investigations.

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|---|---|
| **Casualty type** | Machinery Damage |
| **Location** | North Pacific Ocean, 245 miles from Columbia River entrance, Oregon<br>47°35.31' N, 132°01.49' W |
| **Date** | August 11, 2022 |
| **Time** | 1834 Pacific daylight time<br>(coordinated universal time –7 hrs) |
| **Persons on board** | 23 |
| **Injuries** | None |
| **Property damage** | $3.03 million |
| **Environmental damage** | Up to 1,632 gal hydraulic oil lost from controllable pitch propeller system |
| **Weather** | Visibility 10 mi, winds south-southwest at 5 kts, seas 2–3 ft, air temperature 64°F, water temperature 66°F |
| **Waterway information** | Ocean, depth over 3,000 ft |


**Figure 2.** Area where the *Maunalei* loss of propulsion occurred, as indicated by a red *X*. (Background source: Google Earth)

# 1 Factual Information

## 1.1 Background

The US-flagged, 681-foot-long containership *Maunalei* was built in 2006 by Aker Philadelphia Shipyard, in Philadelphia, Pennsylvania (see figure 1). Matson Navigation Company, Inc, a subsidiary of Matson Inc, owned and operated the vessel, which had a maximum container capacity of 1,992 TEUs.[2] The *Maunalei* routinely transported cargo among southeast Asia, Guam, Hawaii, and the west coast of the United States.

A single in-line 7-cylinder, slow-speed, two stroke diesel engine, designed by MAN B&W and rated at 29,194 hp, provided propulsion. The engine was directly coupled to a MAN Energy Solution SE Germany-designed controllable pitch propeller (CPP) system, providing a loaded service speed of 22 knots at 108 rpm (see section 1.3.1 for more information on the CPP system).

## 1.2 Event Sequence

On August 4, 2022, at 0130, after completing cargo operations, the partially loaded *Maunalei* departed Tacoma, Washington, with a crew of 23, en route to Anchorage, Alaska.

About 1723, when the vessel was about 26 miles from Brooks Peninsula, located northwest of Vancouver Island, British Columbia, Canada, the third engineer on watch reported an engineering alarm (see figure 2). The engine crew found that the CPP hub head tank was empty. The CPP hub head tank, located in the upper engine room, acted as a reservoir for the storage of hydraulic oil for the CPP hub lubricating system and generated static head pressure for hub lubrication due to the elevation of the tank and oil level within the tank.

An engineer contacted the bridge, took control of the propulsion in the engine control room, and reduced the pitch. After the ship's senior engineering officers (chief engineer and first assistant engineer) consulted with the company's shoreside port engineer via email and satellite phone on how best to address the situation, the watch engineer replenished the hydraulic oil in the hub head tank. The chief engineer

[2] *TEU* is a measure of the carrying capacity of a containership based on the number of 20-foot-long containers the vessel is capable of loading (standard shipping container lengths are 20 and 40 feet).

monitored the rpm and pitch of the propeller and reduced them as needed to decrease the loss of hydraulic oil from the CPP system.

Over the next 3 days, the *Maunalei* continued transiting to Anchorage. According to the chief engineer, the CPP system lost about a liter of hydraulic oil per hour while the vessel transited at full speed. The chief engineer stated that when they brought the throttle back to three-quarters ahead (which involved a reduction of both rpm and blade pitch), the rate of hydraulic oil loss decreased to 0.45 liters per hour. The crew and port engineer believed the CPP system was experiencing a failed blade seal—which would require further assistance and drydocking to repair—so the crew reported the vessel's condition to the US Coast Guard. The Coast Guard and Transport Canada granted the vessel approval to proceed to Anchorage, to offload cargo and receive repairs to the propulsion system.[3]

On August 7, at 1506, the *Maunalei* arrived in Anchorage, escorted by two tugs and oil spill response vessels (to address any environmental contamination from the hydraulic oil leak). Once the containership docked, crews aboard the oil spill response vessels placed an oil boom around the *Maunalei*'s hull to contain any loss of hydraulic oil from the vessel. The containership's crew began cargo operations, and MAN technicians and the port engineer boarded the vessel to assist the crew in further examining, testing, and troubleshooting the CPP system. The technicians, port engineer, and crew determined that the system could not be repaired at the dock and that the vessel should be drydocked to further inspect the propeller blades, hub, and sealing system. The captain and the port engineer informed Coast Guard Sector Columbia River of the situation and received approval for the vessel to transit to Vigor Shipyard, in Portland, Oregon, for emergency drydocking to undergo repairs.

On August 8, at 1454, the *Maunalei* departed Anchorage for Vigor Shipyard. During the transit to Portland, the vessel remained outside Canadian and US waters, about 200 miles from the nearest land, because the CPP system continued to lose hydraulic fluid.

On August 10, Coast Guard Sector Columbia River issued a Captain of the Port Order regarding the *Maunalei*'s transit to Portland for emergency drydocking. In Portland, tugs, spill response assets, and Coast Guard personnel coordinated for the *Maunalei*'s arrival and set up containment to minimize the vessel's oil leakage during its planned transit inbound through the Columbia River to the shipyard.

[3] Transport Canada is the department within the Canadian government responsible for the development of regulations, policies, and services for road, rail, marine, and air transportation in Canada. Transport Canada was involved in the decision to grant the *Maunalei* approval to transit to Anchorage because the vessel was in Canadian waters at the time.

Throughout the evening of August 10 and into the early morning hours of August 11, the loss of hydraulic oil from the vessel's CPP hub lubricating system worsened substantially. At 0856, the crew reduced the system’s rpm and pitch to slow the loss of hydraulic oil and conserve the reserve stock. The engineering crew tried to maintain the quantity of hydraulic oil in the hub system, but consumption increased, exhausting the available hydraulic oil on board the vessel. The engine crew consulted with a technical representative from the CPP manufacturer and then used fresh water to supplement the CPP hub lubricating system hydraulic oil head tank. This action prevented the loss of head pressure in the forward sealing surface of the lip seal, which would have caused the stern tube and hub systems to separate and allowed oil to flow from the stern tube lubricating system into the hub lubricating system.

Throughout the day, the crew continued to fill the CPP hub head tank with fresh water to maintain the hub system head pressure on the lip seal. However, water and hydraulic oil continued to be lost, and the vessel’s engine crew noted that the stern tube lubricating system’s hydraulic oil was being contaminated with water. The engine crew also observed high stern tube oil system temperature. At 1834, the chief engineer, in consultation with the master and the port engineer, decided to shut down the *Maunalei*’s main propulsion engine to prevent further damage to the CPP and stern tube systems and have the vessel towed the remaining distance to the shipyard. At the time, seas were 2–3 feet, and winds were light at 5 knots; the ship’s reported position was about 241 miles northwest of the Columbia River entrance sea buoy.

At 1900, the 112-foot-long, multipurpose tug *Samantha S* was dispatched from Astoria, Oregon; it arrived on scene 24 hours later to tow the *Maunalei* to the shipyard in Portland. The *Samantha S* and the *Maunalei* passed the Columbia River entrance buoy at 1200 on August 14, escorted by three Coast Guard vessels, with the standby tug *Black Hawk* trailing the tow. On August 15, at 0437, the *Maunalei* arrived at Vigor Shipyard.

## 1.3 Additional Information

### 1.3.1 Controllable Pitch Propeller System

#### 1.3.1.1 General

In a CPP system, the blades are not fixed in position but are fastened to the hub in a way that allows them to rotate and thereby change pitch. The blade pitch determines both the vessel’s speed and its direction (forward or astern) through the water. To increase vessel speed, the blades are set at a higher pitch that increases the distance traveled per shaft revolution. Lowering the pitch decreases the distance traveled per revolution, thereby slowing the vessel. To change the vessel's direction from ahead to astern, the blades are rotated from a positive pitch to a negative pitch. Neutral position rotates the blades to a place where the thrust ahead and astern is equal, resulting in zero net thrust, although the propeller continues to rotate.

CPP systems are custom designed for individual ships. The blades are engineered for a particular hull and according to the vessel's performance requirements and operating conditions, with the aim of maximizing propulsion efficiency and minimizing noise and vibration.

The *Maunalei*'s MAN Energy Solution Mark 5 CPP system was installed and commissioned at COSCO Nantong Shipyard, in Nantong, China, in October 2020. (A new stern tube, propeller shaft, forward and aft seals, and main engine fly wheel coupling were also installed at the shipyard.)

The CPP system consisted of five propeller blades, each secured to the hub by seven bolts, through a blade coupling flange, servo piston, hub cylinder assembly, and an intermediate shaft system. The bolts for each blade were situated with three on the forward side of the blade (1.1 through 1.3) and four on the after side (1.4 through 1.7) (see figure 3). Bolt no. 1 (1.1) began at the 4 o'clock position, and bolt holes were numbered in the counterclockwise direction. When facing the blade base, the trailing edge of the blade was in the 12 o'clock position, and the leading edge of the blade was in the 6 o'clock position.

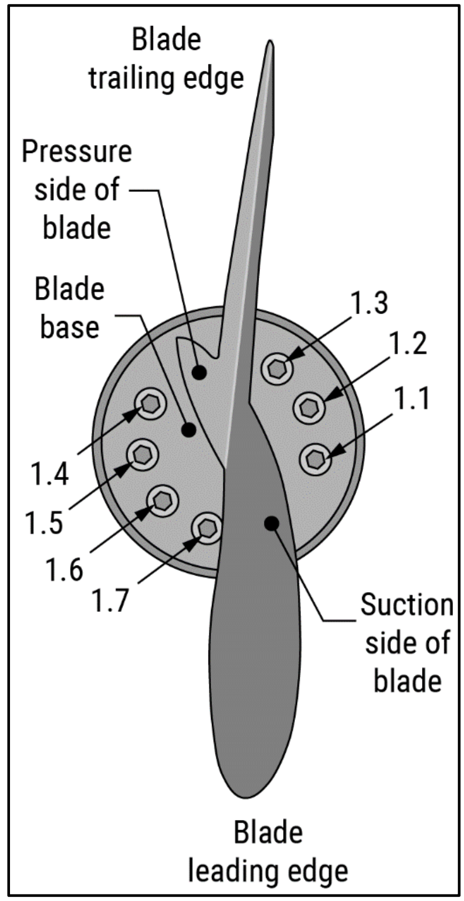


**Figure 3.** *Maunalei* propeller blade no. 1 bolt positions.

The blades of the propeller were hydraulically activated (rotated) by hydraulic oil, which was sent to a servo piston, to achieve the desired blade pitch. Various pitch settings would thrust the vessel in the ahead or astern direction without requiring the conventional slow-speed diesel engine to be reversed.

The CPP system contained three separate hydraulic oil systems: a hub lubricating system, a stern tube lubricating system, and a servo hydraulic system (see figure 4). The hub lubricating system was kept under a static pressure by a separate hub head tank; at the time of the casualty, the hub lubricating system was the only system losing hydraulic oil. The stern tube lubricating system provided lubricating oil to the stern tube bearings and seals; a stern tube head tank kept the bearings and seals under static pressure. The servo hydraulic system was enclosed in the servo cylinder of the hub and was fed by a hydraulic power pack. The hub and stern tube lubricating systems had separate, independent hydraulic systems and head tanks but shared a common forward stern tube lip seal. The sealing surface of the lip seal was maintained by slightly higher pressure in the hub system. Upon a large loss of hydraulic oil in the hub system and head tank, the system head pressure would be reduced, and the lip seal would no longer be able to prevent oil flowing from the stern tube hydraulic system into the hub lubricating system.

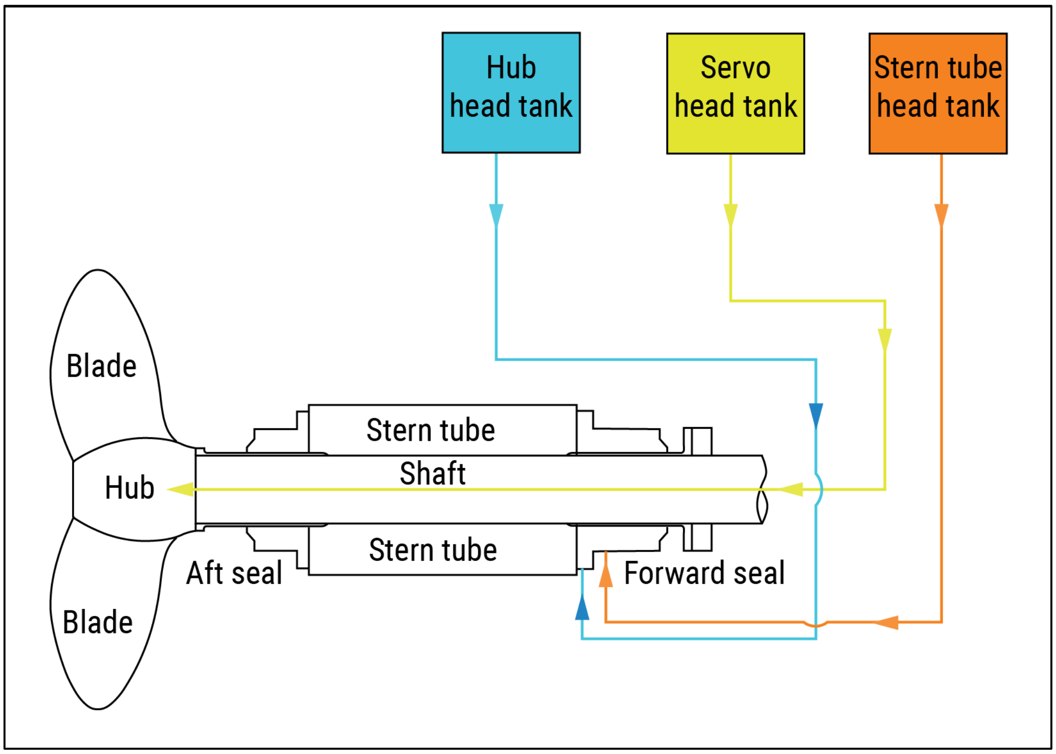


**Figure 4**. Simplified schematic of hydraulic oil system head tanks for CPP system on *Maunalei*.

### 1.3.1.2 Damage and Repairs

On August 15, a diver performed an underwater survey of the CPP blades and hub. The diver discovered that two of the propeller blades, nos. 2 and 4, had fractures at the base (hub) of the blades (see figure 5).

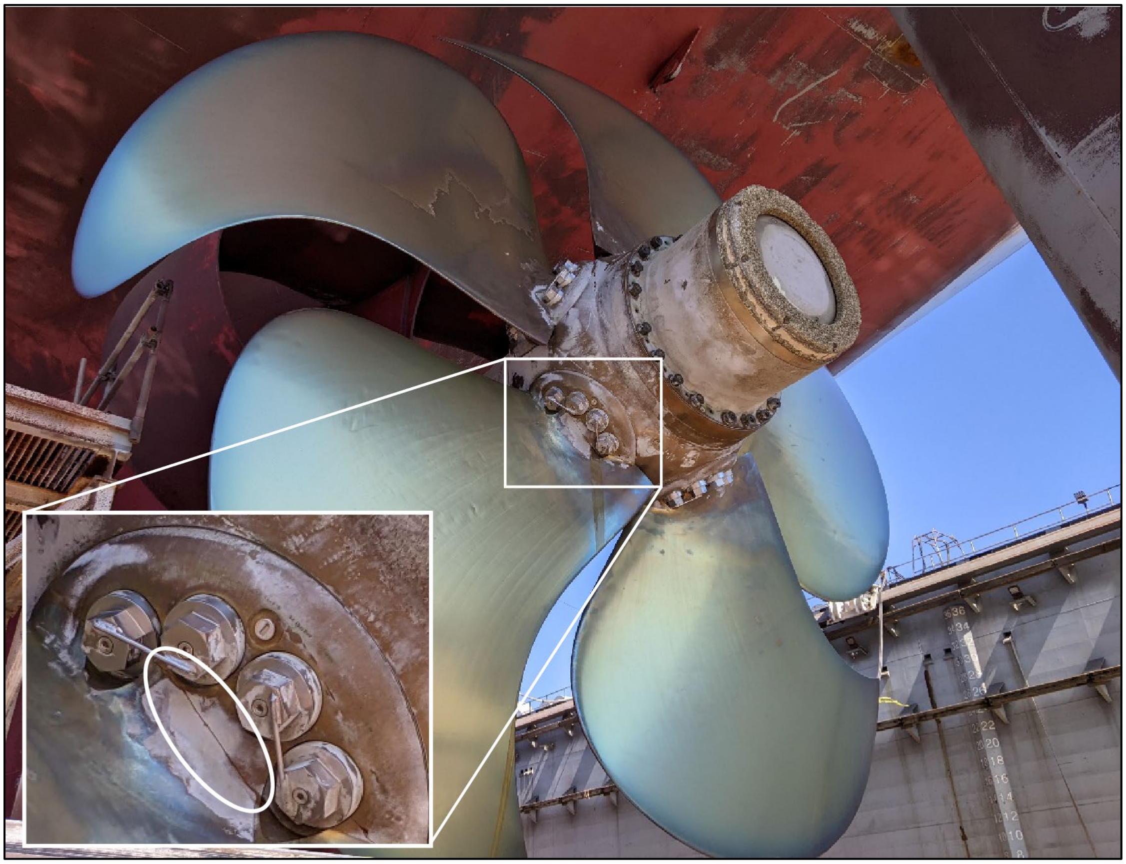

**Figure 5.** The CPP on the *Maunalei* after the casualty, showing a fracture (*inset*) at the base of the no. 4 blade. (Background source: Coast Guard)

After the underwater survey, the vessel was drydocked on August 17 at Vigor Shipyard. The no. 2 blade base (foot) had free surface cracks in the way of the nos. 2.6 and 2.7 bolt holes and between the no. 2.1 bolt recess hole to the blade's leading edge (suction side) (see figure 6). The no. 4 propeller blade base had a fracture at the hub in the way of the leading edge, extending through the bolts, approaching the trailing edge. This fracture was determined to extend through the thickness of the base of the blade.

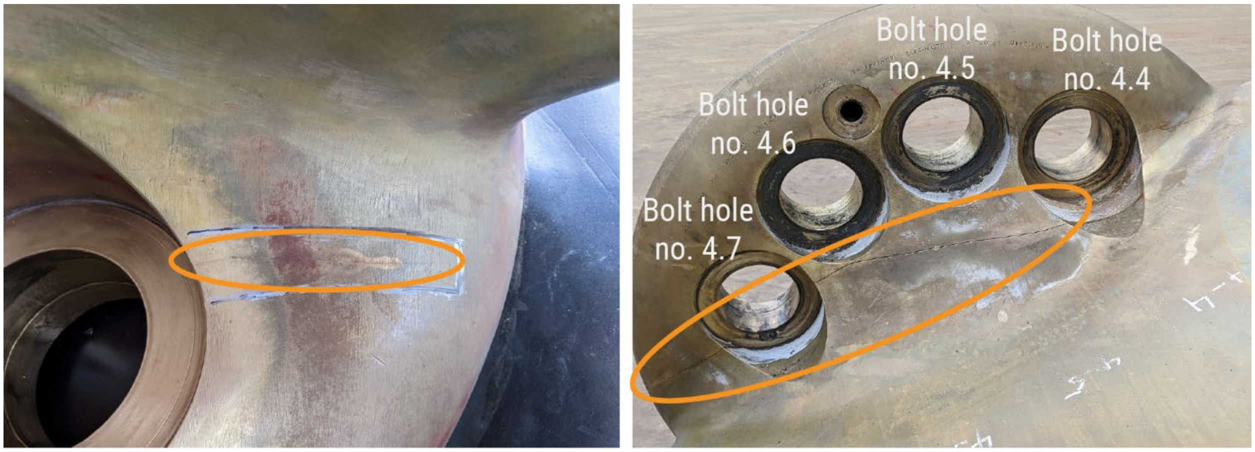


**Figure 6.** Fractures (circled in orange) on propeller blade no. 2, suction side (*left*) and no. 4, pressure side (*right*). (Background source: Coast Guard)

Coast Guard marine inspectors, a surveyor from DNV (the vessel's classification society), representatives for the propeller manufacturer, and port engineers from the owner/operating company examined the *Maunalei* while it was drydocked. The propeller blades were pressure washed, inspected, and dye-penetrant tested. Oily water from the CPP hub system was observed seeping from the no. 4 blade base fracture near blade bolt hole nos. 4.6 and 4.7.

On August 18, shipyard personnel removed both the no. 2 and 4 blades from the CPP hub, and temporary repairs began the following day. The no. 4 fractured blade was replaced with a new spare blade that the owner/operator provided, and the fractured blade was sent off for further examination and testing by the vessel's marine underwriters. Shipyard personnel grinded out the fractures and performed a weld specification procedure—approved by both the CPP manufacturer and classification society—on the no. 2 blade to return the material to its original thickness.[4]

On August 29, after all repairs to the CPP system were completed and the stern tube system was flushed and renewed with hydraulic fluid, the *Maunalei* was refloated, and blade pitch tests were conducted at the pier. The test results were satisfactory to the attending class surveyor, manufacturer, and company representatives. There was no observed change in fluid levels of the CPP and stern tube head tanks during the testing. However, the engine manufacturer recommended that the owner and classification society limit the engine power and engine rpm while underway to reduce the dynamic cyclic stress (forces) on the base

[4] Weld repairs are not normally conducted in base of propeller blades as per class rules; however, no additional spare blades were readily available from the manufacturer.

of the blades until the manufacturer and third party could further evaluate the blades' design.

The *Maunalei* returned to service and made one round trip to Anchorage, Alaska, with the engine manufacturer-recommended restrictions. The crew reduced the main engine power from a maximum continuous rating of 21,770 kilowatts to 9,159 kilowatts (43% of the maximum continuous rating). Engine speed was reduced from a normal speed of 108 rpm to 90 rpm. Based on the reduction of speed and operational limitations, the company deemed the vessel not commercially viable for the intended service. The *Maunalei* returned to Portland and was laid up on September 19 until new blades could be installed and the existing blades could be modified at Vigor Shipyard (see section 1.3.2).

#### 1.3.1.3 Postcasualty Testing

On November 8, after examining and testing the no. 4 blade fractures, a third-party company hired by the *Maunalei* marine underwriters released a report of their findings. The report stated that there was no evidence of significant corrosion, wear, or impact damage to the blade. The report confirmed the presence of two cracks at the hub bolt hole counterbore edges.[5] Additionally, the report stated that the

> appearance of the crack fracture surfaces and the ratchet marks observed at the bolt hole counterbore edges were visually consistent with progressive cracking [caused by] high-cycle fatigue that initiated at the bolt hole counterbore edges.

The report also stated that a cross-section of one of the bolt hole counterbores measured a radius of about 0.62 millimeters, which, according to the report, did not meet the original manufacturer's designed machining radius of 0.8 millimeters (see figure 7).

[5] A *counterbore* is a flat-bottomed, cylindrical hole used to provide a flat, recessed mounting surface for its paired part (in this case, a bolt).

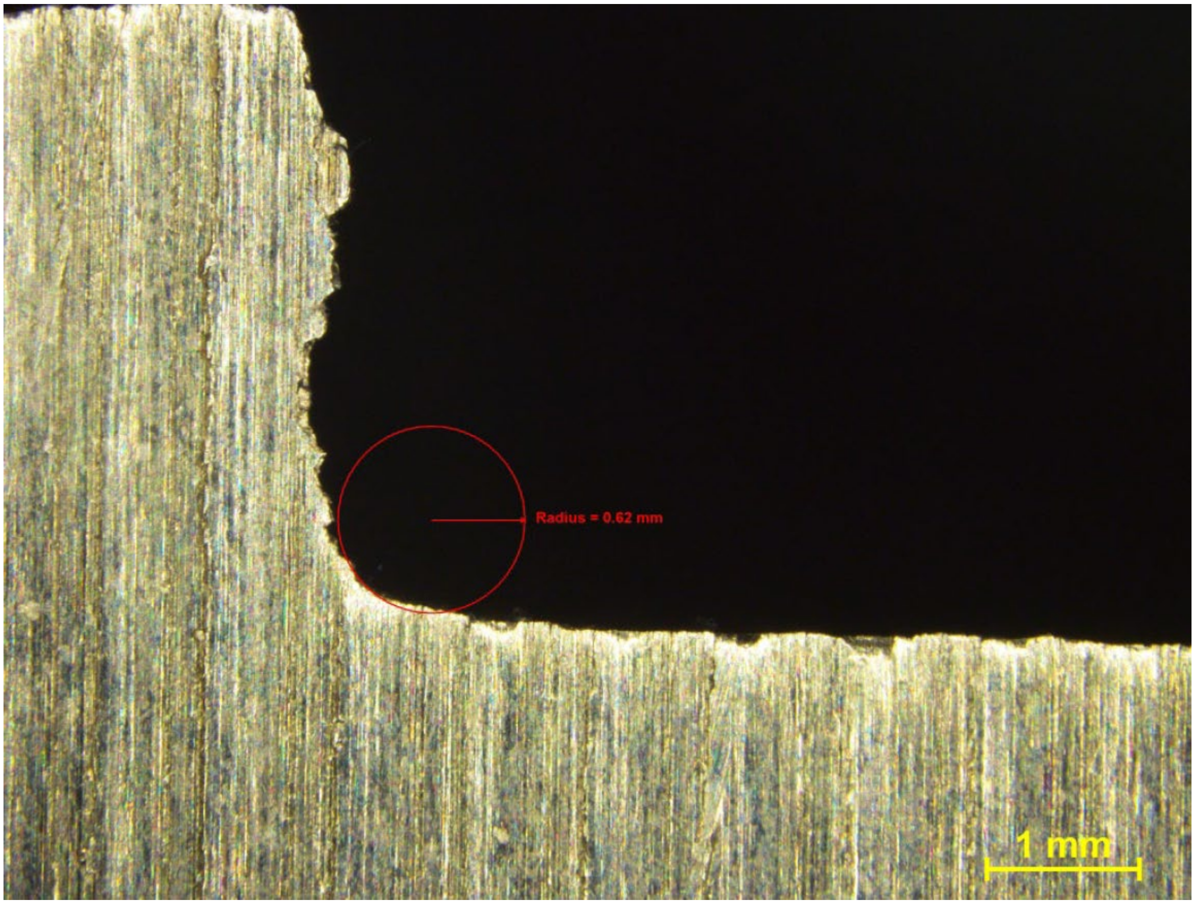


**Figure 7.** The optical stereomicroscopic examination of the no. 4 blade bolt hole counterbore cross-section measured a radius of 0.62 millimeters. (Source: SOCOTEC)

A section of the hub region was tested to analyze its elemental composition. The test results showed that the section met all manufacturer material composition specifications, except for silicon content: the specimen tested at 0.17% by weight, while the manufacturer required a maximum of 0.10% by weight.

Four specimens sectioned and machined from the hub region were tested for toughness by a Charpy notched bar impact test, which measured the material's tendency to resist breaking when subjected to sudden shock. The specimens averaged 9.5 Joules (7 foot-pounds); the manufacturer required 21 Joules (15.5 foot-pounds) when tested at 10°C (50°F) in accordance with ASTM E23.[6]

Further third-party laboratory testing was performed on a specimen from the no. 4 blade at the request of the marine underwriters. This testing revealed that the tensile test results of the specimen did not conform to manufacturer specifications.

[6] ASTM International, "ASTM E23-18: Standard Test Methods for Notched Bar Impact Testing of Metallic Materials," 2023, https://www.astm.org/e0023-18.html.

Additionally, the specimen did not meet manufacturer requirements for tensile strength minimum, yield stress minimum, or elongation minimum (see figure 8).

| SPECIMEN ID | ($N/mm^2$) TENSILE STRENGTH | ($N/mm^2$) YIELD STRESS (0.2% OFFSET) | (%) ELONGATION IN 5D (MANUAL) | (%) REDUCTION OF AREA | FRACTURE LOCATION | KEY (C/NC/R) |
|---|---|---|---|---|---|---|
| REQUIRED | Min | Min | Min | Report | Report | |
| | 630 | 250 | 16 | | | |
| - 22-37161-1 | 442* | 213* | 7.5* | 7.5 | Outside Middle 50% of GL | NC |
| * NON-CONFORMANCE | | | | | | |

**Figure 8.** Results of third-party tensile testing of a *Maunalei* no. 4 blade specimen. (Source: Laboratory Testing Inc)

## 1.3.2 Postcasualty Actions

In September 2022, the CPP system manufacturer completed a review of their propeller blade foot (blade base) machining drawings. They revised the spotface machining of the internal radius for all seven bolt hole counterbores on the *Maunalei* CPP system from 0.8 millimeters to 4.0 millimeters.[7] The manufacturer's revised blade foot machining drawings were finalized on September 15 (see figure 9).

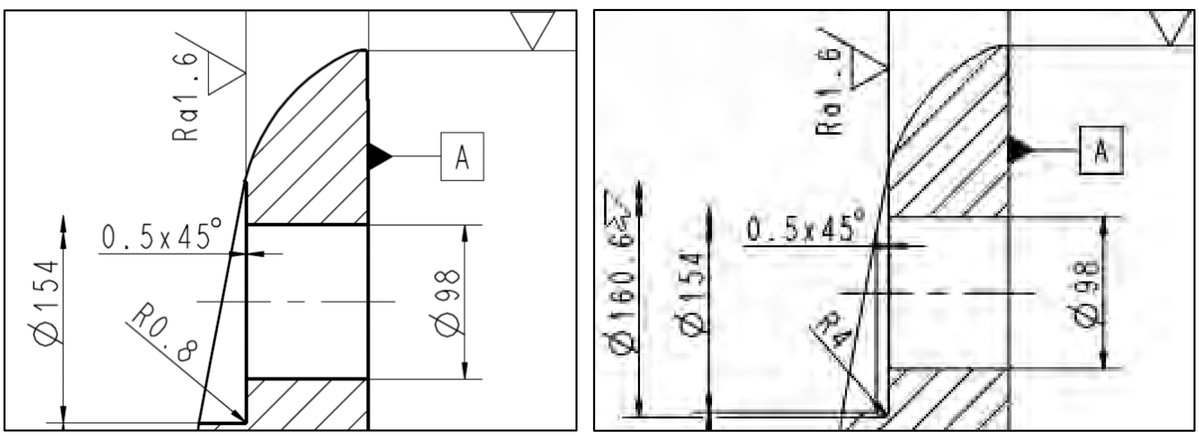


**Figure 9.** CPP blade original (*above*) and revised (*below*) machining drawings reflecting the increased internal radius required for the bolt holes. (Source: MAN Energy Solutions)

[7] *Spotface machining* of a hole is a very shallow counterbore hole, meaning it is a basic cylindrical hole with a wider but shallow pit. Instead of allowing the fastener to sit fully below the level of the workpiece's surface, a spotface hole is sunk just enough to create a level surface for the bolt head to rest against. They are commonly used when the workpiece has an uneven surface. A spotface's depth typically defaults to the minimum necessary to place the fastener's full diameter onto an even surface at a 90° angle.

Additionally, the blade manufacturer completed a finite element analysis for the blades on the *Maunalei* CPP, subjecting the blade to various conditions to determine the root cause of the casualty. According to their resulting report, "high stress concentrations…combined with the large load variations in normal service operation could have caused the incidents [with the CPP system]." The report stated that the postcasualty modifications made to the blade foot machining (increasing the radius to 4.0 millimeters) increased the safety factor 40%, sufficiently reducing the high stress concentration on the blade foot.

The report stated that the blade crack and fracture on the *Maunalei* were the first the manufacturer had experienced on one of their five-bladed propellers. The manufacturer tested other five-bladed propellers on similar vessels. Even when exposed to a higher number of hours and cycles of operation—wherein the manufacturer expected to see failures—the other blades showed no signs of cracking. Additionally, the manufacturer calculated a safety factor for these other blades and found it to be similar to the safety factor calculated for the *Maunalei* with the machining modifications.

The *Maunalei* was drydocked for a second time in November 2022 at Vigor Shipyard. Two newly manufactured replacement propeller blades were installed in the nos. 2 and 3 blade positions. Propeller blade nos. 1, 3, 4 (the no. 4 spare was previously installed August 2022), and 5 were removed from the vessel and transported for modification as recommended by the manufacturer (4.0-millimeter machining radius). MAN service engineers were on site to oversee the work and inspect the blades for fractures before and after modifications.

The hub and stern tube lubrication systems' hydraulic oil fluid was flushed and replenished. Manufacturer technicians, classification society personnel, and Coast Guard representatives witnessed the replacement, and repairs were considered final and permanent on November 22.

# 2 Analysis

On August 4, while the *Maunalei* was underway en route to Anchorage, the engine crew discovered the vessel's CPP hub lubricating system was leaking hydraulic oil. The engine crew attempted to mitigate the loss of hydraulic oil and its effect on the propulsion system by reducing the pitch of the propeller as needed and replenishing the hydraulic oil in the CPP hub head tank. The engine crew believed the CPP system had experienced a blade seal failure, but, because the vessel was at sea, they could not attempt repairs, and the vessel continued to Anchorage.

Three days later, the vessel arrived in Anchorage, where technicians boarded the vessel, examined and tested the CPP system, and determined the vessel should be drydocked to further inspect and repair the system. After the port engineer and captain informed the Coast Guard of the situation, the vessel headed toward a shipyard in Oregon for an emergency drydocking. On the voyage, despite their efforts, the loss of hydraulic oil continued to worsen—so much so that they began using fresh water to supplement the hydraulic oil in the CPP system. The system continued to lose the combined water and hydraulic oil, and the crew noticed the hydraulic oil in the stern tube lubricating system was being contaminated with water. Because the stern tube lubricating system was compromised, the continued use of fresh water as a substitute for hydraulic oil to lubricate and seal the system could have rendered the propulsion system inoperable, risking a full seizure of operation and the potential for the ingress of seawater into the machinery space. As a result, the chief engineer and master decided—in consultation with the owner/operating company—to shut down the main engine due to concerns that water in the stern tube system would cause additional damage to the propulsion system.

A day after the propulsion loss, a tug arrived and towed the vessel to the shipyard for repairs. At the shipyard, a diver conducted an underwater survey and found fractures and cracks on two of the propeller blades (nos. 2 and 4). The free surface cracks found on the no. 2 blade did not extend to the base of the hub and therefore would not have allowed hydraulic oil to leak. The fracture on the no. 4 blade was larger, extending from the hub near the leading edge, through the bolts, and approaching the trailing edge. Additionally, postcasualty examination and testing found that the potable water used to supplement the hydraulic oil during the casualty transit drained from the no. 4 blade, but not the no. 2 blade. Therefore, the fracture in the no. 4 blade base of the CPP system allowed hub hydraulic oil to exit the CPP system, diminishing the fluid reservoir to a level that the crew felt was unsafe to continue to operate the system.

Postcasualty testing completed by a third-party company found no significant corrosion, wear, or impact damage to the propeller blade that might have caused the fractures. Instead, the company found that the cracks and fractures on the no. 4 blade initiated at the bolt hole counterbore radius and were consistent with progressive cracking due to high cycle fatigue. The company also found that the bolt hole counterbore radius did not meet manufacturer machining requirements (the radius was about 0.2 millimeters smaller than the required 0.8 millimeters). Additionally, the no. 4 blade did not meet other manufacturer design specifications, such as material specifications for Charpy impact toughness, tensile strength, yield strength, or percent elongation. Lastly, the chemical composition of the blade did not meet compositional requirements (the silicon content exceeded the specified minimum). Propeller blades require adherence to specified engineering design, material selection, and manufacturing requirements to maintain optimum performance and extend fatigue life. Because the no. 4 blade did not meet manufacturer design specifications, it was more susceptible to high cycle fatigue, which resulted in the development of cracks and fractures in the blade base. As a result of the casualty, the CPP blade manufacturer revised the internal radius requirement—enlarging it—for all seven bolt hole counterbores to improve fatigue fracture resistance.

Based on the *Maunalei*'s no. 4 blade not meeting specifications and the manufacturer's postcasualty finite element analysis of other five-bladed CPP systems on similar vessels (which did not identify any other instances of cracks), the crack and fracture that developed on the no. 4 blade of the *Maunalei* CPP system was likely an isolated occurrence.

# 3 Conclusions

## 3.1 Probable Cause

The National Transportation Safety Board determines that the probable cause of the loss of propulsion on the containership *Maunalei* was a crack developing in a controllable pitch propeller blade base and progressing into a fracture due to high cycle fatigue as a result of the blade not meeting manufacturer design specifications.

| **Vessel** | ***Maunalei*** |
| --- | --- |
| **Type** | Cargo, General (Containership) |
| **Owner/Operator** | Matson Navigation Company, Inc. (Commercial) |
| **Flag** | United States |
| **Port of registry** | Honolulu, Hawaii |
| **Year built** | 2006 |
| **Official number (US)** | 1181627 |
| **IMO number** | 9273686 |
| **Classification society** | DNV |
| **Length (overall)** | 680.6 ft (207.5 m) |
| **Breadth (max.)** | 97.8 ft (29.8 m) |
| **Draft (casualty)** | 33.5 ft (10.2 m) |
| **Tonnage** | 25,324 GT ITC |
| **Engine power; manufacturer** | 29,194 hp (21,770 kW); MAN B&W 7L70MC-C8 2-G1 diesel engine |

NTSB investigators worked closely with our counterparts from **Coast Guard Sector Columbia River** throughout this investigation.

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable cause of the accidents and events we investigate, and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for any accident or event investigated by the agency. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

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For more detailed background information on this report, visit the NTSB Case Analysis and Reporting Online (CAROL) website and search for NTSB accident ID DCA22FM039. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting—

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