



**Bundesstelle für Seeunfalluntersuchung**  
**Federal Bureau of Maritime Casualty Investigation**  
Federal Higher Authority subordinated to the Ministry  
of Transport and Digital Infrastructure

## **Investigation Report 405/18**

### **Serious Marine Casualty**

**Destruction of the main engine's turbocharger  
with subsequent fire in the engine room  
of the BALTIC BREEZE  
in the North Sea  
on 14 October 2018**

21 July 2020

This investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG). According to said Law, the sole objective of this investigation is to prevent future accidents. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this report.

Issued by:  
Bundesstelle für Seeunfalluntersuchung – BSU  
(Federal Bureau of Maritime Casualty Investigation)  
Bernhard-Nocht-Str. 78  
D-20359 Hamburg



Director: Ulf Kaspera  
Phone: +49 40 3190 8300  
posteingang-bsu@bsh.de

Fax: +49 40 3190 8340  
[www.bsu-bund.de](http://www.bsu-bund.de)

## Table of Contents

1	SUMMARY.....	5
2	FACTUAL INFORMATION.....	7
2.1	Photograph of the ship .....	7
2.2	Ship particulars.....	7
2.3	Voyage particulars.....	8
2.4	Marine casualty or incident information .....	8
3	COURSE OF THE ACCIDENT AND INVESTIGATION .....	10
3.1	Course of the accident .....	10
3.1.1	Turbocharger explosion.....	10
3.1.2	Firefighting by the crew .....	11
3.1.3	Subsequent events.....	12
3.2	Investigation .....	15
3.2.1	BALTIC BREEZE .....	15
3.2.2	Start of the investigation .....	16
3.2.3	Investigations made on 15 October 2018.....	16
3.2.4	Investigations made on 17 October 2018.....	21
3.2.5	Further progress of the investigation .....	27
3.2.6	Additional examinations .....	34
3.2.7	Other findings .....	35
3.2.8	Crew.....	35
4	ANALYSIS.....	36
4.1	Damage to the turbocharger.....	36
4.2	Firefighting by the crew .....	40
5	CONCLUSIONS.....	41
6	SOURCES .....	43
7	ANNEXES.....	44

## Table of Figures

Figure 1:	Photograph of the BALTIC BREEZE .....	7
Figure 2:	Scene of the accident .....	8
Figure 3:	AIS track of the BALTIC BREEZE on 14 October 2018.....	12
Figure 4:	Schematic of turbocharging.....	17
Figure 5:	Technical drawing of turbocharger .....	17
Figure 6:	Main engine's destroyed turbocharger .....	18
Figure 7:	Main engine's destroyed turbocharger .....	18

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Figure 8: View of the main engine and turbocharger platform .....	19
Figure 9: Locations of the diffuser ring and part of the compressor wheel .....	19
Figure 10: Damage to lights and cables .....	20
Figure 11: Damage to the paint coating.....	20
Figure 12: Printout from the alarm printer .....	22
Figure 13: Turbocharger platform with air filter body .....	23
Figure 14: Turbocharger shaft with hydraulic nut.....	24
Figure 15: Close-up of the fracture surface on the turbocharger shaft .....	24
Figure 16: Half of the compressor wheel .....	25
Figure 17: Bearing shield on compressor side.....	25
Figure 18: Fracture surface on the shaft with fatigue fracture.....	26
Figure 19: Fractured base of the turbocharger .....	26
Figure 20: Compressor side of the charging air cooler .....	27
Figure 21: Compressor casing with air inlet guide .....	28
Figure 22: Air filter body .....	28
Figure 23: Removal of other components.....	29
Figure 24: Torn off turbine blades and crack in bearing .....	30
Figure 25: Damaged nozzle ring.....	30
Figure 26: Split compressor wheel .....	31
Figure 27: Rear of the compressor wheel with sealing labyrinths.....	32
Figure 28: Deformed and broken compressor blades with material smearing.....	32
Figure 29: Broken compressor blades with virtually no deformation.....	33
Figure 30: Extract from Figure 29 .....	33
Figure 31: Fracture surface of the rotor shaft with fatigue and forced fractures.....	38

## 1 SUMMARY

On 14 October 2018 the Singapore-flagged car carrier BALTIC BREEZE was en route from Drammen to Cuxhaven.

The ship passed south-west Heligoland and approached the pilot boarding point for the River Elbe. The reduction in the speed of the main engine was to start one hour before reaching this position. The second engineer officer and another crew member manned the engine room for this purpose.

The automatic reduction in speed was started at about 0140<sup>1</sup>. The main engine's turbocharger surged briefly shortly afterwards, which was followed by the mechanical destruction of the turbocharger on the compressor side. The oil that escaped in the process ignited and caused a fire.

The second engineer officer responded to the fire by activating the HI-FOG fire extinguishing system, which was also installed in the area of the turbocharger platform, and actuating the main engine fuel supply's quick-closing valve. He also informed the bridge, from where the fire alarm for the ship was triggered. The two crew members then left the engine room and went to the muster station.

The master notified Vessel Traffic Service (VTS) German Bight of the fire in the engine room at 0200 after organising the initial response on board the ship. The VTS then notified the competent authorities on the German coast.

The ship's command of the BALTIC BREEZE assumed early (at 0243) that the fire was extinct and confirmed this after an inspection in the engine room at 0435.

To begin with, response personnel from the Federal Police (BPOL) patrol vessel BAD BRAMSTEDT were deployed to investigate the situation on board the ship. In addition, other police boats and ships from the Shipping Administration were alerted. After the Central Command for Maritime Emergencies (CCME) assumed overall responsibility for coordinating the operation, a BPOL helicopter flew a firefighting unit (FFU) from Cuxhaven Fire Service to the ship and winched the latter down onto her at 0714.

After an inspection by the fire service and the ventilation of the engine room, the ship was to that extent ready again. The destroyed turbocharger prevented the safe continuation of her voyage, however. The local VTS therefore ordered the acceptance of tugs suitable for entering Cuxhaven.

With two assisting tugs but under her own power, the voyage to Cuxhaven began at 1804. The BALTIC BREEZE then made fast at Seebäderbrücke at 0024 on 15 October 2018. The water pollution control vessel MELLUM and a fire watch from the fire service, which was on board the distressed vessel, escorted the tow up until that point.

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<sup>1</sup> All times shown in this report are local = UTC+2 hours (Central European Summer Time - CEST).

The CCME stood down from its role as overall coordinator of the operation when the ship reached her berth.

Neither the destruction of the turbocharger nor the fire resulted in any fatalities or injuries. No water pollution was reported.

## 2 FACTUAL INFORMATION

### 2.1 Photograph of the ship



Figure 1: Photograph of the BALTIC BREEZE

### 2.2 Ship particulars

Name of ship:	BALTIC BREEZE
Type of ship:	Car carrier
Flag:	Singapore
Port of registry:	Singapore
IMO number:	8312590
Call sign:	9VRQ
Owner:	Wallenius Lines Singapore
Operator:	Wallenius Marine Singapore
Charterer:	United European Car Carriers
Year built:	1983
Shipyard:	Kurushima Dockyard Co. Ltd.- Onishi Yard
Classification society:	Lloyds Register
Length overall:	164.01 m
Breadth overall:	28.00 m
Draught (max.):	9.91 m
Gross tonnage:	29,979
Deadweight:	12,466 t
Engine rating:	7,934 kW
Main engine:	Mitsubishi, 1 x 6UEC60HA
(Service) Speed:	18 kts
Hull material:	Steel
Hull design:	Double bottom
Minimum safe manning:	12

### 2.3 Voyage particulars

Port of departure:	Drammen, Norway
Port of call:	Cuxhaven, Germany
Type of voyage:	Merchant shipping/international
Cargo information:	Heavy goods vehicles
Manning:	22
Draught at time of accident:	$D_f = 5.70\text{ m}$ , $D_a = 6.50\text{ m}$
Pilot on board:	No
Canal helmsman:	No
Number of passengers:	None

### 2.4 Marine casualty or incident information

Type of marine casualty:	Serious marine casualty (destruction of turbocharger and subsequent fire in engine room)
Date, time:	14/10/2018, 0150
Location:	North Sea, German Bight, near buoy E3
Latitude/Longitude:	$\varphi 54^\circ 03.7'N$ $\lambda 007^\circ 52.0'E$
Ship operation and voyage segment:	High seas
Place on board:	Engine room
Human factors:	No
Consequences:	Turbocharger destroyed and major fire damage in the engine room

Extract from Navigational Chart 87,  
Federal Maritime and Hydrographic Agency (BSH)

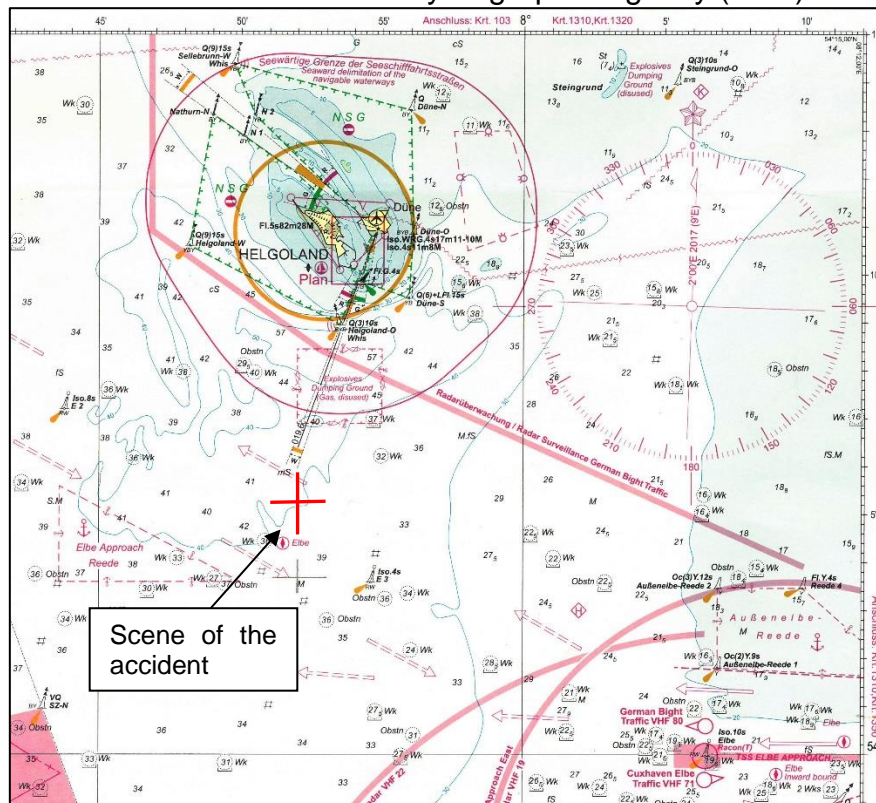


Figure 2: Scene of the accident



## 2.5 Shore authority involvement and emergency response

Agencies involved:	VTS German Bight, CCME, BPOL, Waterway Police (WSP) Schleswig-Holstein, WSP Cuxhaven, Cuxhaven Fire Service
Resources used:	BPOL patrol vessel BAD BRAMSTEDT (BP 24) with boarding team (BT), BPOL helicopter, coastal patrol boats HELGOLAND and BÜRGERMEISTER BRAUER, water pollution control vessels MELLUM and NEUWERK (NEUWERK on standby at Cuxhaven), FFU from Cuxhaven Fire Service, FFU from Bremerhaven Fire Service on standby, oil surveillance aircraft from the German Navy
Actions taken:	Crew succeeds in extinguishing the fire; ship anchors near buoy E3; BT from BAD BRAMSTEDT carries out preliminary investigations on board the BALTIC BREEZE; MELLUM takes temperature measurements on the shell plating; MELLUM designated on-scene coordinator (OSC); CCME assumes overall responsibility for coordinating the operation; FFU (comprising ten members) transported to ship by helicopter, confirmation by FFU that the fire was extinguished, followed by fire watch by fire brigade to the port; master of ship orders necessary tugs; ship is accompanied by moored tugs to Cuxhaven and moors there with tug support; WSP Cuxhaven and BSU commence investigations

## 3 COURSE OF THE ACCIDENT AND INVESTIGATION

### 3.1 Course of the accident

The account of the course of the accident is based on the written statements of the master, the second engineer officer<sup>2</sup> and another member of the engine room crew<sup>3</sup>, as well as on entries in the deck and engine log book.

On 14 October 2018 the Singapore-flagged car carrier BALTIC BREEZE was en route from Drammen to Cuxhaven. She sailed out of the port of Drammen at about 2030 on 12 October 2018. The ship's cargo comprised nine heavy goods vehicles and two excavators.

An officer in charge of the navigational watch and a lookout manned the bridge of the ship at the beginning of the events that were to ensue. In accordance with usual practice at night, there was no engine room watch.

The course was altered to 120° at 0112 on 14 October 2018, bringing the ship on a course parallel to the recommended route from buoys E1 to E3. As the voyage continued, the ship passed south-west Heligoland and approached the pilot boarding point for the River Elbe. A force 5-6 Bft south-easterly wind prevailed in the early hours of the morning. The air and water temperatures stood at about 16 °C and visibility was clear.

#### 3.1.1 Turbocharger explosion

The officer in charge of the navigational watch phoned the 2<sup>nd</sup> engineer and the oiler at 0120 and asked them to man the engine room. The ship had reached the boundary defined previously (one hour to pilot boarding point). Five minutes later the engine room was manned and the 2<sup>nd</sup> engineer started the second auxiliary diesel engine. A short time later the officer in charge of the navigational watch requested that they start reducing the main engine's speed. The 2<sup>nd</sup> engineer acknowledged this and started the automatic reduction at about 0140. The reduction started from a speed of 105 min<sup>-1</sup>. Since the reduction in speed also entails a drop in scavenging pressure, the 2<sup>nd</sup> engineer switched on the auxiliary ventilator for the main engine to maintain scavenging pressure. He then proceeded from the engine control room (ECR) to the engine room and carried out an inspection there. When he returned to the ECR a little later, he heard the turbocharger surging<sup>4</sup>. According to the 2<sup>nd</sup> engineer, the automatic system had reduced the speed by about 4 min<sup>-1</sup> by this point in time.

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<sup>2</sup> Referred to below as 2<sup>nd</sup> engineer.

<sup>3</sup> Referred to below as oiler.

<sup>4</sup> Surging starts when the compressor's operating points shift into the unstable range due to a reduction in rate of delivery (flow rate) or rise in discharge pressure [...]. Surging is characterised by cyclical delivery and return flows of the compressed medium accompanied by strong vibrations, pressure surges and a rapid temperature rise in the compressor. Potential consequences are bearing, rubbing, rotor or blade damage, which could lead to breakdowns. <https://de.wikipedia.org/wiki/Pumpschutz> [in German], retrieved 24 March 2020.

Before the 2<sup>nd</sup> engineer was able to take any action, he heard an explosion [sic]<sup>5</sup> and the alarm for a fire in the scavenge trunk followed soon afterwards.

The 2<sup>nd</sup> engineer then looked through the large window between the ECR and engine room and saw high flames between the turbocharger platform and cylinder heads. White smoke was also visible. He then pressed a button to start the HI-FOG fire extinguishing system for this area. Following that, he notified the officer in charge of the navigational watch on the bridge about what had happened and that he would now stop the main engine. He also asked him to sound the fire alarm.

After the phone call the main engine was brought to a standstill by actuating the fuel supply's quick-closing valve. The 2<sup>nd</sup> engineer also switched off the auxiliary ventilators to reduce the flow of supply air. This all happened extremely quickly. The two crew members then left the ECR via the emergency exit.

In the minutes leading up to the explosion, the oiler checked the water level in the main engine cooling water's expansion tank. When he was near the freshwater distillation system, he heard an alarm. He immediately went to the ECR to check the cause of the alarm. He could then see the explosion of the main engine's turbocharger through the window between the ECR and engine room. He left the ECR with the 2<sup>nd</sup> engineer soon afterwards.

The 2<sup>nd</sup> engineer and oiler were not injured during the incident. They were both able to go to the muster station and later carry out the roles assigned to them in the task-allocation plan in the event of fire.

The master was woken at about 0150 by the rapid drop in the speed of the main engine. The fire alarm for the ship sounded shortly afterwards. The master then hurried to the bridge and directed the firefighting measures from there.

### **3.1.2 Firefighting by the crew**

Under the leadership of the Chief Engineer and in coordination with the bridge team and the backup team, the crew began immediate fire fighting. To gain an overview of the situation the 4. Engineer and one of the oilers tried to enter the engine room with respiratory protection via the steering gear compartment at 0413. They were successful but it was decided not to go any further because of the amount of smoke there. Flames were not detected. Nevertheless, the chief engineer officer arranged for the Hi-FOG fire extinguishing system to be triggered in other areas.

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<sup>5</sup> This section refers to the mechanical destruction of the turbocharger as 'explosion'. It is actually not an explosion but rather a sudden destruction due to mechanical damage.

A reduction in smoke was found during a subsequent inspection, which was also carried out via the steering gear compartment.

### 3.1.3 Subsequent events

This account of the subsequent events is based on the sources already referenced in Section 3.1. Additionally, the incident log of the Maritime Emergencies Reporting and Assessment Centre (MERAC) and mission reports of the BAD BRAMSTEDT, the HELGOLAND, the Cuxhaven Fire Service and the report file of VTS German Bight were referred to.

The BALTIC BREEZE's master notified VTS German Bight at 0200 on 14 October 2018 that his ship was reportedly not under command due to a fire in the engine room. At this point the ship was located to the west of buoy E3. This message was forwarded to the MERAC and the Maritime Rescue Coordination Centre (MRCC) Bremen within the framework of the joint information system. At 0209 the master advised that there would be no casualties on board. Information on the seat of the fire was still not available.

As an initial measure, the MERAC started to notify the FFUs responsible for ship fires from Cuxhaven Fire Service and Bremerhaven Fire Service, as well as the BPOL's helicopter wing at 0208. Information was also sent to various response personnel from the police, who then started an operation. In addition, the MELLUM was alerted and sailed from Heligoland to the distressed vessel.

The BALTIC BREEZE's master informed the VTS at 0221 that he did not yet have a comprehensive overview of the situation. At the same time, he asked for two tugs to be ordered via the ship's agency so as to move to a roadstead with their assistance.

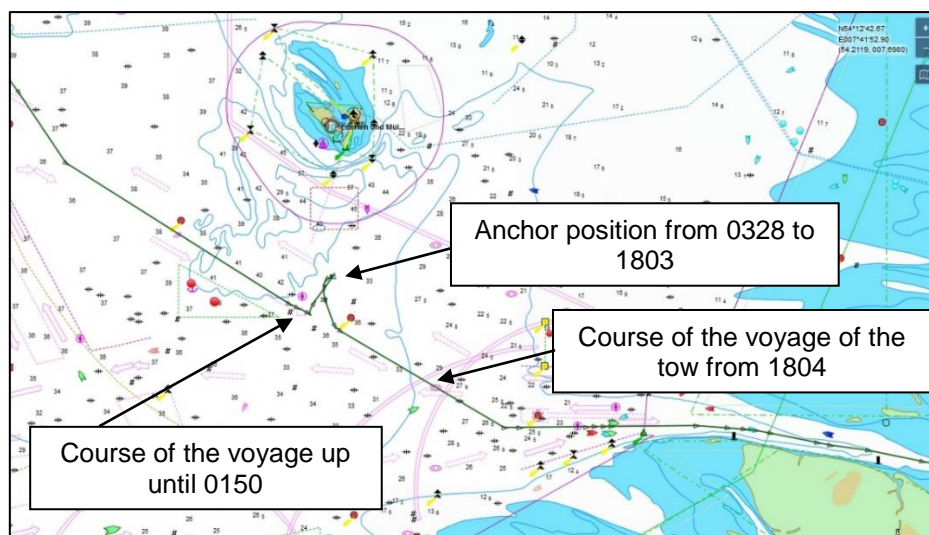


Figure 3: AIS track of the BALTIC BREEZE on 14 October 2018<sup>6</sup>

<sup>6</sup> Source: MarineTraffic.

At 0243 the master transmitted the information that the fire was reportedly extinguished and the crew was now reportedly checking the situation. He advised the VTS that reportedly no additional firefighters were needed on board (0246).

The tugs ordered by the master set sail for the distressed vessel at 0300. Since their voyage was expected to take about 2.5 hours, the ship anchored. BAD BRAMSTEDT reached the BALTIC BREEZE a short time later.

The anchor manoeuvre was completed at 0328, which was also about the time at which the ship's crew started to survey the engine room. As enough crew members were not available at this point, the master initially put back the BPOL's request for deployment of a pilot ladder for an inspection on board.

The MELLUM reached the distressed vessel at 0340 and began measuring the temperatures on the shell plating. Measurements of between 26 °C and 29 °C were made in the aft section on the starboard side of the BALTIC BREEZE.

The master enabled the BPOL to carry out an inspection at 0430 and a pilot ladder was deployed.

The BPOL's BT boarded at 0501. During the approach, they detected a temperature of 33 °C on the ship's shell plating. The HELGOLAND also arrived at the scene at this point and started to implement traffic safety measures there.

At 0508 the captain confirmed to the VTS that a team from the ship had entered the engine room and that no flames could be detected there.

At 0520 the CCME advised all bodies involved that it had exercised its right to intervene and had assumed overall responsibility for coordinating the operation.

Officers from the BPOL were briefed on the cause of the fire while they were inspecting the distressed vessel. The officers found temperatures of up to 50 °C and flaking paint level with the main deck on the engine room bulkheads. The master announced in connection with the inspection that he was now in agreement with the deployment of professional firefighters on board the ship.

At 0557 the CCME decided that a BPOL helicopter should fly two groups of five firefighters from the Cuxhaven FFU to the distressed vessel.

The MELLUM was declared OSC at 0611. A short time later the NEUWERK was ordered to sail for Cuxhaven and make preparations there for the embarkation of more firefighters and firefighting equipment from Bremerhaven.

The helicopter with the first five firefighters took off from Nordholz at 0638. They finished winching down onto the BALTIC BREEZE at 0714.

The two tugs (VB RÖNNERBERG and BERNE) ordered by the distressed vessel's master arrived at the ship at 0700.

The FFU began to survey the engine room after it had been briefed by the BPOL's inspection team and the captain. Furthermore, ventilation of the engine room began in consultation with the FFU. To this end, the watertight integrity established at the beginning of the fire was lifted. Neither open flames nor further smoke development could be detected during the survey. There was no firefighting by the FFU.<sup>7</sup>

The next five firefighters were winched down onto the BALTIC BREEZE at 0820.

After extensive ventilation of the engine room and clearance measurements by the FFU, operations were resumed there. The crew attempted to start the main engine. As events unfolded, the BPOL's BT left the distressed vessel and the BAD BRAMSTEDT was stood down from the operation.

Since the VTS required more powerful tugs for towing the BALTIC BREEZE to Cuxhaven, the tugs VB JADE (75 t bollard pull) and VB WILHELMSHAVEN (51 t bollard pull) were requested. The tugs that arrived earlier on were stood down when they reached the scene at about 1400. The HELGOLAND was also stood down from her mission at this point.

The first five firefighters left the distressed vessel at about 1100. They were taken back to Cuxhaven on board the BÜRGERMEISTER BRAUER. The other firefighters stayed on board the BALTIC BREEZE and kept a fire watch until Cuxhaven. Since additional firefighters were no longer necessary, the CCME had already stood down FFU Bremerhaven and the NEUWERK from the operation.

The main engine of the BALTIC BREEZE was ready for operation again after a test run at 1730 to that extent that it could be operated at slow speed and with local control. The VTS was informed of this.

At 1740 the crew of the BALTIC BREEZE began hoisting in the anchor. Following that, the connections were established with the tugs at the bow and stern and the voyage could begin at 1804. The BALTIC BREEZE sailed under her own power. The MELLUM escorted until she reached buoy 31a on the River Elbe at 2345.

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<sup>7</sup> Both this deployment of the fire brigade and the later fire watch were necessary to obtain the entry permit for the ship after the fire.

The BALTIC BREEZE was moored at the Seebäderbrücke in Cuxhaven at 0024 on 15 October 2018 and the CCME then stood down from its role as overall coordinator of the operation.

### **3.2 Investigation**

The technical documentation available on board from the turbocharger's manufacturer was referred to for the investigation. Documents such as service reports and maintenance logs were also available. In addition, the recordings of the alarm printer were analysed. No information was available on board that would have allowed conclusions to be drawn about the speed reduction process or at least when this started. In this respect, it is not possible to establish a temporal relationship between the alarms that occur and state of the main engine at that time. Such a recording is not mandatory.

The BALTIC BREEZE was equipped with a simplified voyage data recorder (S-VDR) from Consilium. Although it was possible to read out data during the first survey of the ship, these data did not refer to the accident period because the master failed to trigger an emergency backup. It should be noted that S-VDRs do not record engine data according to the performance standards.

The BSU found during the review of the data available that there was no data recording whatsoever between 1420 on 10 October 2018 and 0558 on 14 October 2018. The system's manufacturer was questioned about this finding and stated that the most recent required annual performance test had been carried out on 1 August 2018. The technical issues detected by the crew during or before that were eliminated during maintenance. The system has reportedly operated without any problems since then. The cause of the problem identified by the BSU could not be clarified in the course of this investigation.

#### **3.2.1 BALTIC BREEZE**

The BALTIC BREEZE was a ship suitable for carrying passenger vehicles, heavy goods vehicles and their trailers or semi-trailers, construction machinery and other rolling stock. The ship was equipped with the usual adjustable decks for such cargo so as to be able to adapt stowage space according to requirements. The ship had a total of nine vehicle decks on which 3,200 vehicles could be carried. Vehicles entered the ship via a ramp installed aft on the starboard side. The ship also had a side ramp on the starboard side.

The BALTIC BREEZE's engine room was located aft. The engine casing ran from the freeboard deck along the vessel's centreline through all decks, tapering upward.

The particulars of the turbocharger destroyed during the incident are as follows: type: MET 66 SC; serial number: 10627; specification: DC 3G46ED6L; year built: 2007; manufacturer: Mitsubishi.

Due to the damage to the turbocharger, the cost incurred for cleaning and repair, as well as the age of the ship, the BALTIC BREEZE was declared a constructive total loss in November 2018 and decommissioned.

### **3.2.2 Start of the investigation**

The crew of the HELGOLAND notified the person on call at the BSU of the marine casualty at 0937 on 14 October 2018. Contact was then made with the CCME for further information. Using this channel the BALTIC BREEZE's master was requested to trigger the emergency backup on the ship's S-VDR via the OSC at about 1500.

As it was clear that the BALTIC BREEZE would not reach Cuxhaven until the early hours of the morning on 15 October 2018, an inspection of the ship immediately after her arrival at 0024 on 15 October 2018 was dispensed with. The owner was notified of this.

### **3.2.3 Investigations made on 15 October 2018**

The investigations on board the distressed vessel began at about 1000 on 15 October 2018. After a meeting with representatives of the owner and the master, the first step was to start backing up the data on the S-VDR. To gain an initial overview, the engine room was surveyed at the same time.

In the engine room it was found that there was major fire damage above the main engine. The crew stated that the gantry crane was no longer available because the electrical connections had been damaged. The turbocharger was destroyed on the compressor side. At the same time, the air filter body and the compressor casing still attached to it had been removed from their actual position about 3 m forward in the longitudinal direction of the ship. One half of the compressor wheel had been propelled a long way through the engine room and was now on another platform.

The basic operating principle of a turbocharger is shown in the schematic below.



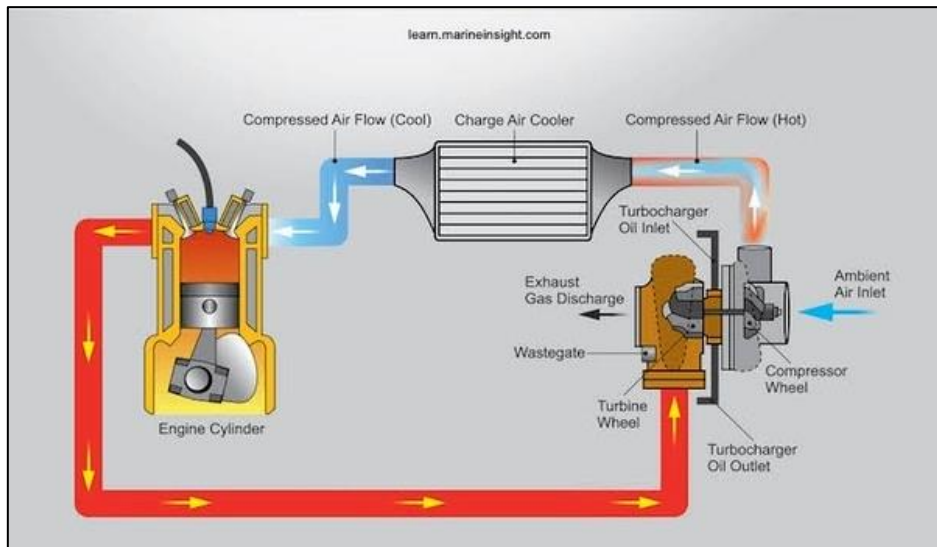


Figure 4: Schematic of turbocharging<sup>8</sup>

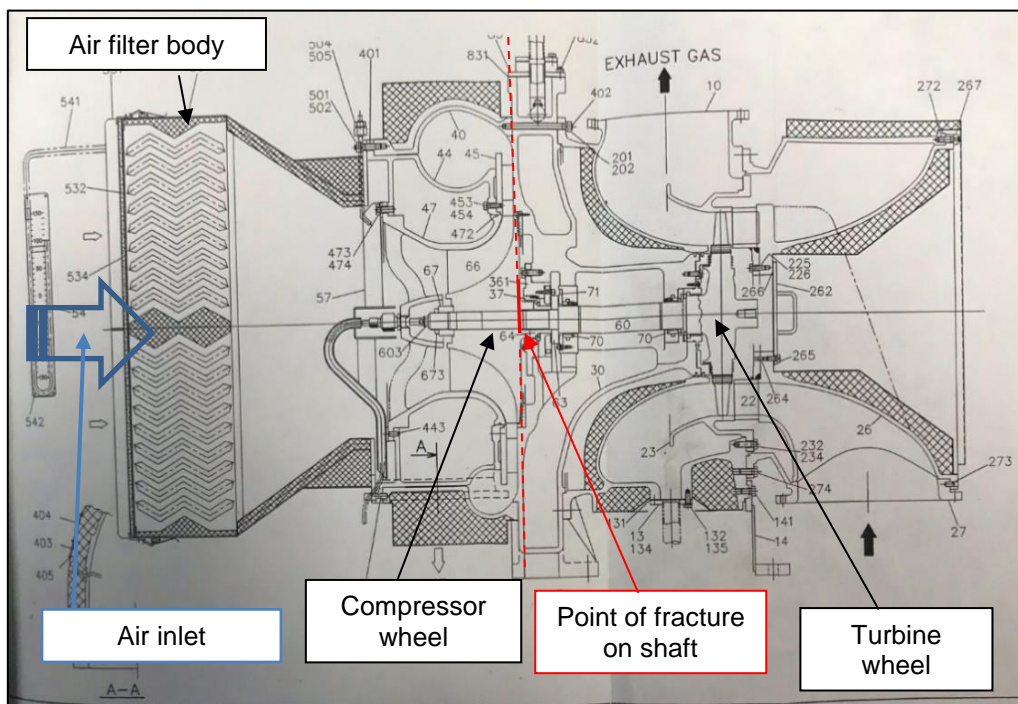


Figure 5: Technical drawing of turbocharger<sup>9</sup>

<sup>8</sup> <https://www.marineinsight.com/main-engine/what-is-turbocharger-surfing/>, retrieved 31 March 2020

<sup>9</sup> Extracted from the turbocharger's manual.

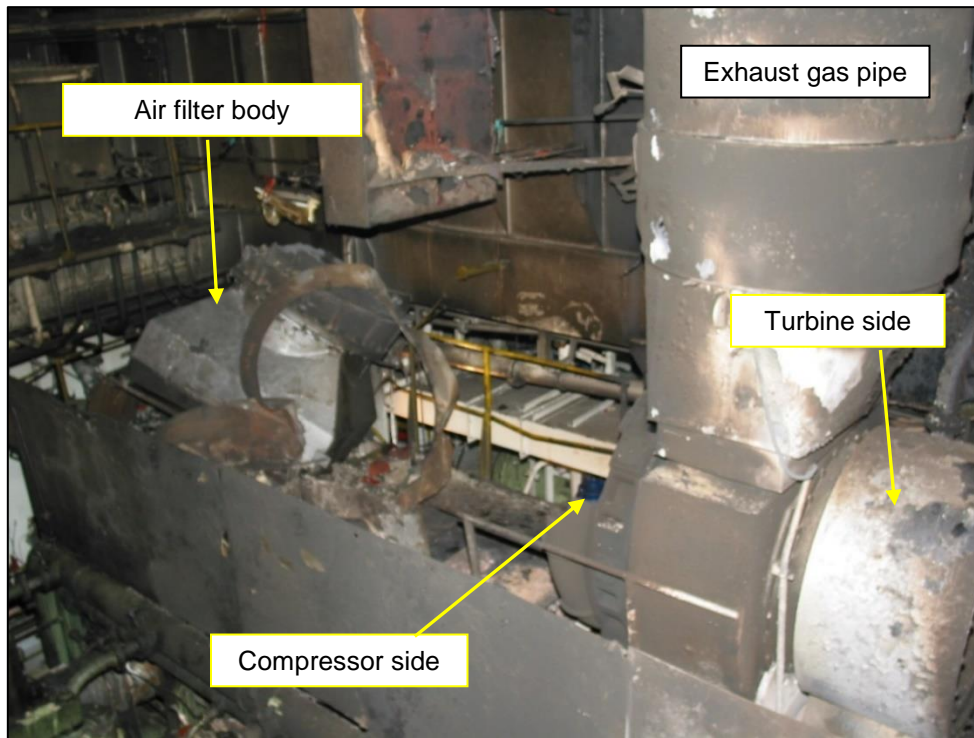


Figure 6: Main engine's destroyed turbocharger

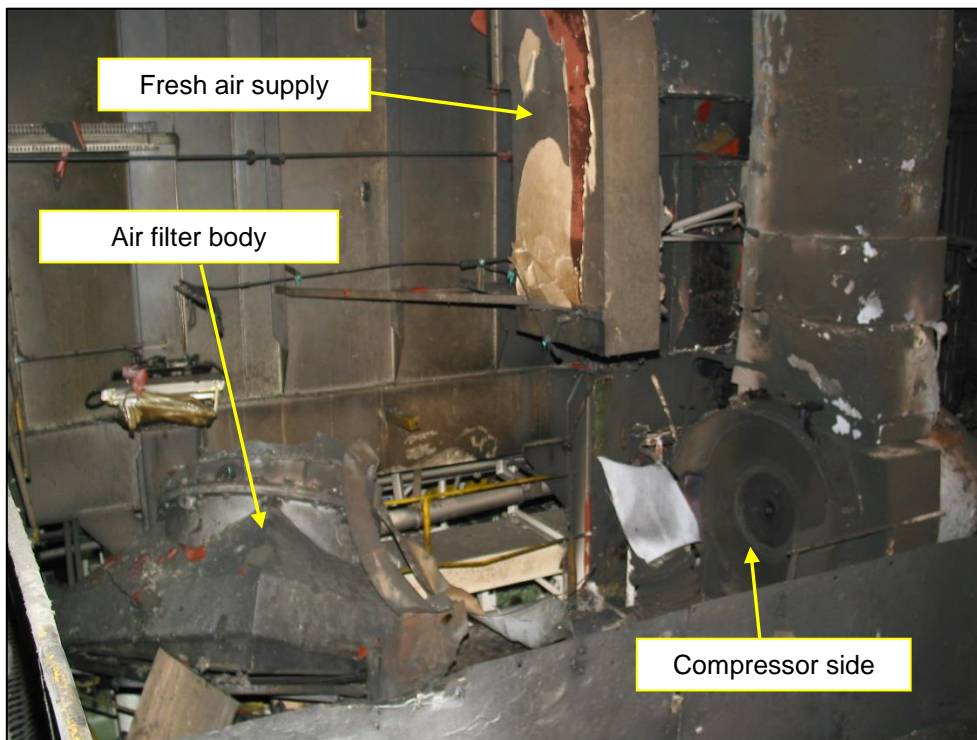


Figure 7: Main engine's destroyed turbocharger  
View of the compressor side.

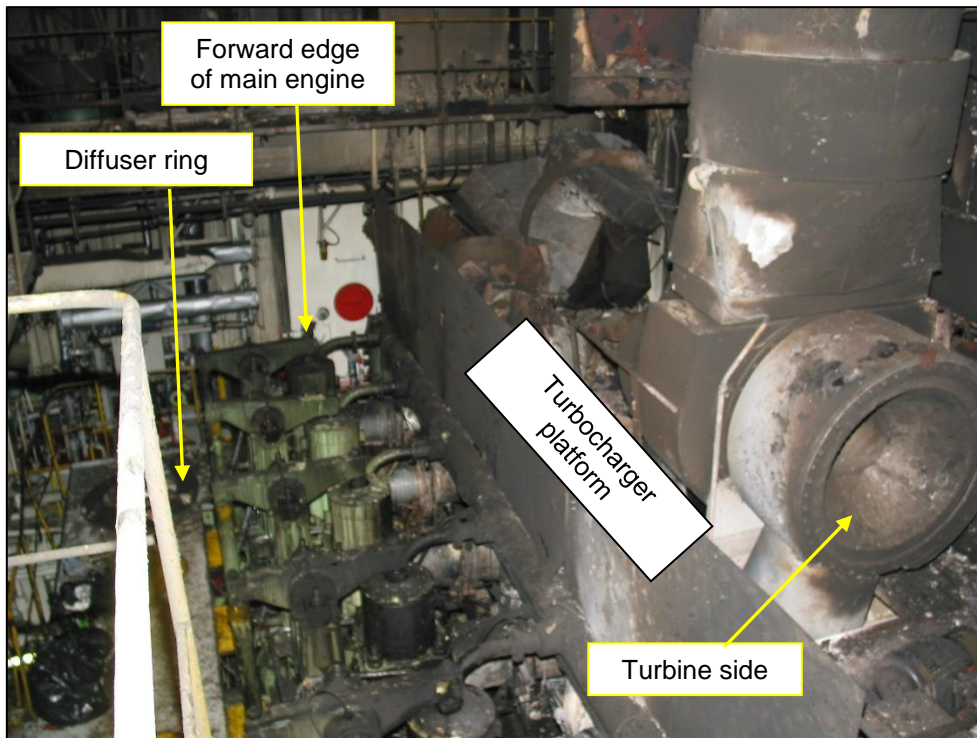


Figure 8: View of the main engine and turbocharger platform  
 Location of the diffuser ring to the left on the platform of the cylinder station.

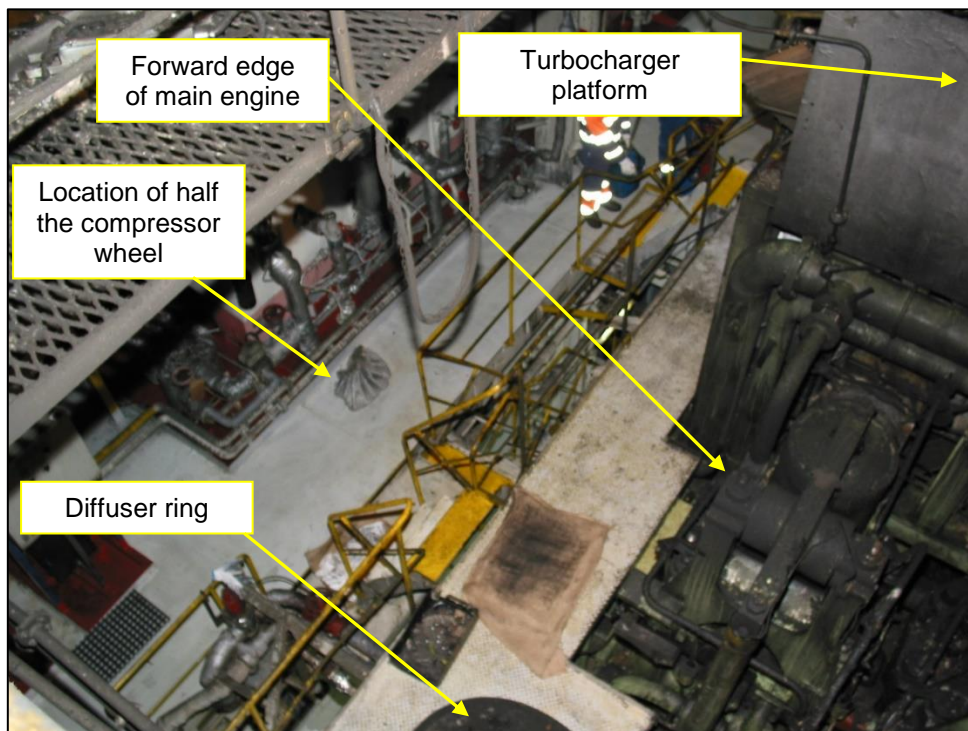


Figure 9: Locations of the diffuser ring and part of the compressor wheel

The crew of the BALTIC BREEZE was only available for general questioning to initially clarify what had happened. Detailed testimonies were submitted later in writing.

The following fire damage was discovered during the first survey, *inter alia*:

- the complete engine casing was heavily fouled by soot. Various wiring harnesses and lights had been exposed to heat stress (Figure 10);
- heat stress had caused paint to flake off on the outside of the engine casing (Figure 11).



Figure 10: Damage to lights and cables



Figure 11: Damage to the paint coating

The outside of the engine casing on the starboard side of the freeboard deck is shown here.

### 3.2.4 Investigations made on 17 October 2018

Based on the initial findings made on 15 October 2018, the BSU's director decided on 16 October 2018 that this event warranted a full investigation. This required the assistance of an expert. Prof. Dr.-Ing. Behrens from the Institute of Thermal Power and Machine Tools at the Bremerhaven University of Applied Sciences offered his services.

As regards the investigation, the owner was informed by BSU that the area of the turbocharger platform and components belonging to the turbocharger had been secured.

On 17 October 2018 the two crew members located in the engine room at the time of the accident were questioned with the expert present. The following information was taken down in the process:

*"The most recent service on the BALTIC BREEZE's turbocharger was [...] carried out in 2016 in Poland. The undersigned has received a corresponding report from Messrs Turbo Poland Ltd. sp. z o.o. (Turbocharger Service) in Gdansk. The report is dated 10 August 2016. According to documents on the website, Turbo Poland is a certified partner of Mitsubishi for overhauling MET turbochargers.*

*The turbocharger's rotor was removed and the components cleaned and measured during the service in question. The casings and the silencer were also cleaned and parts of the silencer material were replaced. Furthermore, the rotor was dynamically balanced. A corresponding balancing report is available (Annex 4).*

*According to the crew, the turbocharger has been in use for some 12,000 operating hours since this overhaul."<sup>10</sup>*

This information on the course of the accident could also be obtained:

*"[...] the reduction in speed was made via the main engine's control system and configured so that each minute the engine speed reduced by 2 rpm. About two minutes after the speed reduction was initiated, the 2<sup>nd</sup> engineer heard two short surge strokes from the turbocharger and then noticed a fire in the engine room immediately afterwards [...]"<sup>11</sup>*

The analysis of the alarm printer recordings (Figure 12) yielded the following information:

*"The recordings of the engine automation system's alarm printer [...] contained an initial damage report at 014523 in the form of an alarm for the scavenge trunk fire. That was followed by a slow-down alarm for the main engine at 014530 – the slow-down was confirmed at 014537.*

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<sup>10</sup> Prof. Dr.-Ing. R. Behrens: Expert opinion on the engine damage on the motor vessel 'BALTIC BREEZE' (IMO No: 8312590). 2018, page 5. Referred to below as 'Opinion on engine damage'.

<sup>11</sup> Ibid., page 12.

The scavenge trunk fire alarm repeated several times, each with increasing temperatures measured. More alarms occurred subsequently. The oil mist detector alarm triggered at 014612 and excessive exhaust gas temperature in the turbocharger inlet was reported immediately afterwards. At 014620, the alarm printer registered that the lubricating oil pressure in the turbocharger was too low. This damage is likely to have occurred earlier, as the oil pressure loss presumably resulted from increased oil flow due to the damaged bearings. More alarms concerning the main engine and its limits follow and at 015128 the engine was shut down automatically. The alarms that followed occurred as a result of the main engine being shut down and of the engine room fire but are not directly relevant to the damage.<sup>12</sup>

ALARM LIST for Baltic Breeze							DC C20		
Date	Time	Tagname	Tag description	Func	Value	Eng.	Cond.	State	
14-10-18	01:02:49.014	COMERR B006	COMM ROS2 ESU DPU6 (5/21)	XA			FAIL	RETURN	
14-10-18	01:02:49.014	COMERR B005	COMM ROS2 CA DPU5 (5/20)	XA			FAIL	RETURN	
14-10-18	01:45:23.687	SCAFIRE3	SCAVENGE AIR FIRE CYL. 3	TIAH	62.6	°C	HIGH	ALARM	
14-10-18	01:45:24.806	SCAFIRE5	SCAVENGE AIR FIRE CYL. 5	TIAH	66.6	°C	HIGH	ALARM	
14-10-18	01:45:25.256	SCAFIRE4	SCAVENGE AIR FIRE CYL. 4	TIAH	64.3	°C	HIGH	ALARM	
14-10-18	01:45:25.736	SCAFIRE6	SCAVENGE AIR FIRE CYL. 6	TIAH	64.9	°C	HIGH	ALARM	
14-10-18	01:45:26.995	SCAFIRE2	SCAVENGE AIR FIRE CYL. 2	TIAH	61.8	°C	HIGH	ALARM	
14-10-18	01:45:28.044	SCAFIRE5	SCAVENGE AIR FIRE CYL. 5	TIAH	90.9	°C	HI-HI	ALARM	
14-10-18	01:45:28.394	SCAFIRE3	SCAVENGE AIR FIRE CYL. 3	TIAH	86.1	°C	HI-HI	ALARM	
14-10-18	01:45:29.173	SCAFIRE4	SCAVENGE AIR FIRE CYL. 4	TIAH	88.6	°C	HI-HI	ALARM	
14-10-18	01:45:29.583	SCAFIRE6	SCAVENGE AIR FIRE CYL. 6	TIAH	86.6	°C	HI-HI	ALARM	
14-10-18	01:45:30.589	SLD 04b	SCAVENGING AIR FIRE	SLD			SLOWDN	ALARM	
14-10-18	01:45:31.922	SCAFIRE2	SCAVENGE AIR FIRE CYL. 2	TIAH	87.6	°C	HI-HI	ALARM	
14-10-18	01:45:36.940	SCAFIRE1	SCAVENGE AIR FIRE CYL. 1	TIAH	57.2	°C	HIGH	ALARM	
14-10-18	01:45:37.279	SAFETY SLD	SLOWDOWN ACTIVE	XA	6.4		HIGH	ALARM	
14-10-18	01:45:38.870	SCAFIRE5	SCAVENGE AIR FIRE CYL. 5	TIAH	202.9	°C	HIGH	RETURN	
14-10-18	01:45:39.389	SCAFIRE5	SCAVENGE AIR FIRE CYL. 5	TIAH	215.8	°C	IFH	ALARM	
14-10-18	01:45:40.469	SCAFIRE2	SCAVENGE AIR FIRE CYL. 2	TIAH	197.0	°C	HIGH	RETURN	
14-10-18	01:45:40.999	SCAFIRE2	SCAVENGE AIR FIRE CYL. 2	TIAH	220.4	°C	IFH	ALARM	
14-10-18	01:45:42.148	SCAFIRE4	SCAVENGE AIR FIRE CYL. 4	TIAH	204.0	°C	HIGH	RETURN	
14-10-18	01:45:42.668	SCAFIRE4	SCAVENGE AIR FIRE CYL. 4	TIAH	214.9	°C	IFH	ALARM	
14-10-18	01:45:43.448	SCAFIRE3	SCAVENGE AIR FIRE CYL. 3	TIAH	203.4	°C	HIGH	RETURN	
14-10-18	01:45:44.028	SCAFIRE3	SCAVENGE AIR FIRE CYL. 3	TIAH	215.6	°C	IFH	ALARM	
14-10-18	01:45:51.555	SCAFIRE6	SCAVENGE AIR FIRE CYL. 6	TIAH	206.8	°C	HIGH	RETURN	
14-10-18	01:45:52.115	SCAFIRE6	SCAVENGE AIR FIRE CYL. 6	TIAH	213.0	°C	IFH	ALARM	
14-10-18	01:45:52.168	SLD 04b	SCAVENGING AIR FIRE	SLD			SLOWDN	RETURN	
14-10-18	01:45:52.280	SAFETY SLD	SLOWDOWN ACTIVE	XA	0.0		HIGH	RETURN	
14-10-18	01:45:54.544	FIRE	FIRE	XA			ALARM	ALARM	
14-10-18	01:45:58.292	SCAFIRE1	SCAVENGE AIR FIRE CYL. 1	TIAH	76.7	°C	HI-HI	ALARM	
14-10-18	01:46:01.458	SLD 04b	SCAVENGING AIR FIRE	SLD			SLOWDN	ALARM	
14-10-18	01:46:06.521	SAFETY SLD	SLOWDOWN ACTIVE	XA	6.4		HIGH	ALARM	
14-10-18	01:46:12.730	SLD 01	OIL MIST HIGH DENSITY	SLD			SLOWDN	ALARM	
14-10-18	01:46:13.178	AL62-06	M/E T/C IN EXH GAS TEMP	TIAH	455.7	°C	HIGH	ALARM	
14-10-18	01:46:15.876	AL28-09	M/E T/C LO OUT TEMP	TIAH	65.5	°C	HIGH	ALARM	
14-10-18	01:46:20.164	AL202	T/C LO IN PRESS LOW	PAL			ALARM	ALARM	
14-10-18	01:46:22.523	AL62-20	M/E CYL 2 EXH GAS DEV TEMP	TIAHL	57.6	°C	HIGH	ALARM	
14-10-18	01:46:26.359	SLD 06	Exh Gas Cyl 1-6 Deviation	SLD			SLOWDN	ALARM	
14-10-18	01:46:31.414	AL62-021	M/E CYL 2 EXH GAS OUT TEMP	TIAHH	455.2	°C	HIGH	ALARM	
14-10-18	01:46:33.461	AL62-19	M/E CYL 1 EXH GAS DEV TEMP	TIAHL	-53.1	°C	LOW	ALARM	

Figure 12: Printout from the alarm printer

<sup>12</sup> Ibid., page 5.

The detailed examination of the turbocharger in question and its technical environment then began. The BSU's expert made the following findings, *inter alia*:

*"The entire compressor of the turbocharger was no longer on it. There were only small parts of the compressor's casing [...] and the air discharge nozzle from spiral to charging air cooler [...]. [...] half of the compressor wheel was located near the intake casing between the position of the turbocharger and the intake casing [Figure 13]."*

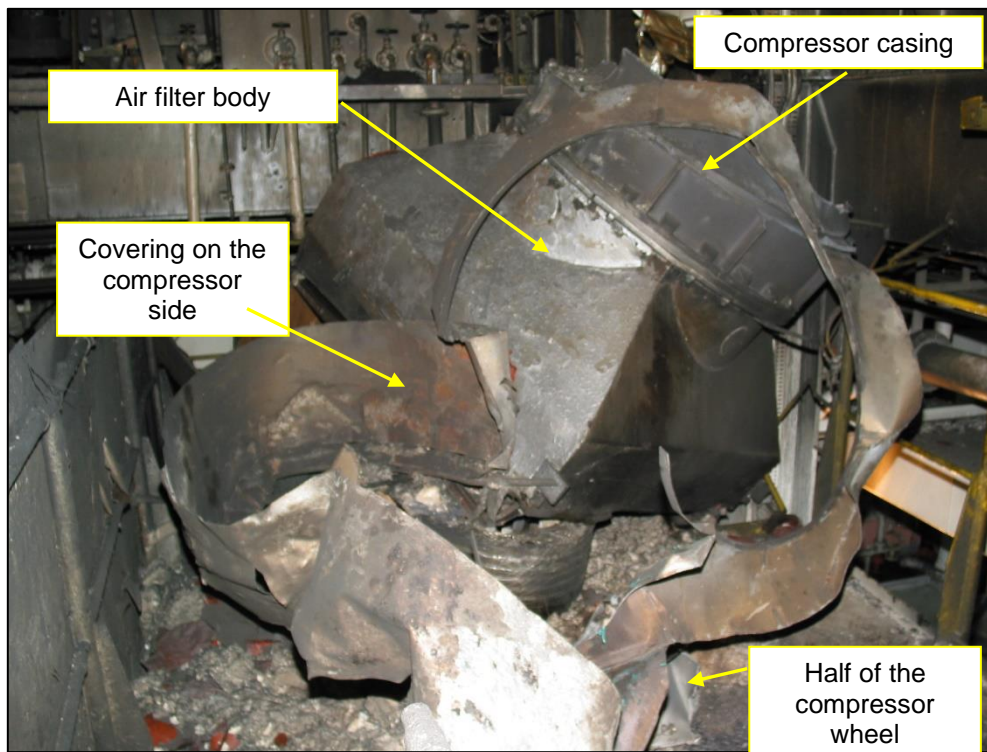


Figure 13: Turbocharger platform with air filter body

View from turbocharger to the air filter body.

*Various fragments of the casing and other turbocharger parts were scattered across the turbocharger platform. The second half of the compressor wheel was located one deck below at the front of the main engine [Figure 8]. The diffuser ring was located on the cylinder station deck [Figures 8 and 9] and heavily deformed. Fragments from the compressor casing were also found around the engine's cylinder station. The end piece of the turbocharger shaft with the hydraulic nut used to tighten and pre-tension the compressor wheel were found near the diffuser. The nut was tight on the end thread while the other end of this shaft part exhibited bending and a fracture surface [Figures 14 and 15]."<sup>13</sup>*

<sup>13</sup> Ibid., page 3.



Figure 14: Turbocharger shaft with hydraulic nut



Figure 15: Close-up of the fracture surface on the turbocharger shaft

*"The compressor wheel is broken in two through the shaft's centreline [...]. The fracture surface shows signs of a forced fracture [...]. The blades of both fragments are completely damaged and in some cases worn down to the body of the compressor wheel [Figure 16]."*





Figure 16: Half of the compressor wheel



Figure 17: Bearing shield on compressor side

[Figure 17] shows the bearing plate of the shaft bearing on the compressor side and the damaged labyrinth seal between the rear wall of the compressor and rear wall of the compressor wheel. The corresponding shaft end with fracture surface is visible in the middle. The so-called attach tab, which creates a positive connection between shaft and compressor wheel, is still on the shaft end. There is major damage in this area, too. For example, two clamping screw heads from the bearing plate have sheared off and the inner labyrinth seal casing has flattened sealing grooves. The fracture surface of the shaft indicates that the fracture started from a machining edge. This is clearly visible in the previous figure. Furthermore, [Figure 18] reveals that a fatigue fracture is evidently visible on the shaft fracture surface in addition to the forced fracture.



Figure 18: Fracture surface on the shaft with fatigue fracture

*The base of the turbocharger was cracked [Figure 19].*



Figure 19: Fractured base of the turbocharger

*All upper decks of the engine room and the upper walkways, e.g. on the cylinder barrel station of the main engine, are covered by splinters and debris from the turbocharger [...].*

*The turbocharger part on the turbine side [...] looks undamaged from the outside at first, apart from the surface fouling by soot and debris lying in this area.*

*The charging air cooler was also checked for damage or obstruction during the survey on 17 October 2018. This involved opening the hood of the charging air cooler on the turbocharger side. Parts of the charging air cooler were heavily fouled by oil, combustion residues and small pieces of debris that probably fell from above during the damage event and fire. The stator lamination from the charging air cooler was inspected after an access cover had been opened. A large number of small splinters were found on the stator lamination, which presumably come from the broken compressor wheel and broken compressor casing. However, no extensive obstruction, e.g. that may have caused the turbocharger to start surging, was detected [Figure 20]."<sup>14</sup>*



Figure 20: Compressor side of the charging air cooler

After completion of the investigation on board, the BSU secured the two parts of the compressor wheel and fragment of the turbocharger shaft and gave them to the expert for further assessment. The securing of most areas of the engine room was lifted on that day.

### **3.2.5 Further progress of the investigation**

To fully investigate the cause the turbocharger had to be dismantled. It was necessary to wait for the owner's decision on the further use of the ship before the turbocharger could be accessed. After this had been made, the BSU arranged and covered the costs for an approved service partner of Mitsubishi to dismantle the turbocharger, take it out of the engine room and then transport it to their workshop.

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<sup>14</sup> Ibid., pages 3-4.

The crew of the ship made every effort to assist with the dismantling works on the BALTIC BREEZE and removal from the ship. Dismantling took place on 20 November 2018. The crew had already taken the air filter body and compressor casing out of the engine room on 16 November 2018. The BSU's investigators monitored all works.



Figure 21: Compressor casing with air inlet guide<sup>15</sup>



Figure 22: Air filter body

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<sup>15</sup> n/a



Figure 23: Removal of other components

The turbocharger was dismantled on 23 November 2018 at the premises of the service partner Scan Turbo Handels- und Service GmbH and with the assistance of its staff. In addition to the expert commissioned by the BSU and an investigator from the BSU, two engineers from the BALTIC BREEZE and a technical superintendent from the owner also attended.

A full description of the dismantling works can be found in the expert's opinion. Extracts from this follow:

*"...Messrs Scan Turbo [had] created a device with which the bearing plate on the compressor side was to be removed so as to make it possible to dismantle the turbocharger's rotor [...]. However, the attempt to pull off the bearing plate failed because the turbocharger shaft was – as described above – bent and the mounting sleeve with claw could not be pulled over the shaft end because of that. As a result, the bearing flange, [...], broke after about 20 mm, [...] and could not be pulled out of the bearing housing any further. It was then decided to knock back the bearing plate and try to force the rotor through the bearing and claw sleeve on the turbine side using a hydraulic press. This idea was ultimately successful and the turbocharger rotor could be pulled out of the casing on the turbine side. The considerable pressing forces that had to be applied damaged the shaft's fracture surface [...]. In addition, the mounting sleeve with claw was pulled with force over the serrations, which then exhibited major damage on the edges [...]."*

*To prepare for the dismantling of the rotor on the turbine side, the nozzle ring and exhaust gas discharge casing on it were already dismantled. It became clear in the process that all turbine blades were torn off about half way up. Some of the torn off pieces were in the lower part of the turbine casing but some had probably disappeared with the exhaust gas flow in the exhaust pipe when the engine was shut down [Figure 24]. Turbine blade sections circulating around the casing may well also have damaged the nozzle ring [Figure 25]."*

*The figure clearly shows that foreign objects have entered the fixed nozzle ring blades from the turbine side.*

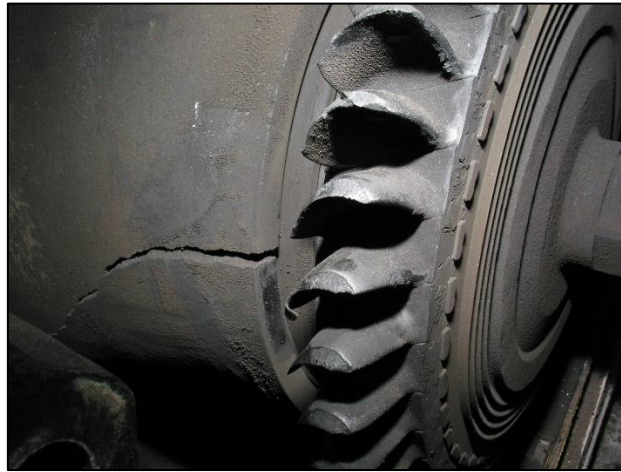


Figure 24: Torn off turbine blades and crack in bearing



Figure 25: Damaged nozzle ring

*Dismantling also revealed that the turbine casing was completely separated from the bearing housing of the turbocharger [...]. Considerable cracking can also be seen in the part of the bearing housing on the turbine side [...].*

*[...] The radial bearing on the turbine side was still in position in the bearing housing [Figure 24]. However, the bearing housing already shows cracking but all components of the bearing block are still largely in position. This figure also clearly shows that the bearing housing has a longitudinal crack. However, this is fouled by soot on the fracture surface, meaning it must have been formed while the engine was still running.*

*[...] The examination of the part of the intake air filter housing on the compressor side [...] did not yield any evidence that elements from the air filter, which might have migrated through the compressor, are missing. Similarly, all elements of the bearing star in the air inlet guide, which covers the speed sensor, were found and could be assembled [...].*

*No parts were missing here, either. Accordingly, it is reasonable to assume that the damage to this bearing star is also caused by the turbocharger damage and that a bearing star fracture with subsequent migration of debris into the compressor wheel did not cause the damage.*



Figure 26: Split compressor wheel

*As described above, the compressor wheel is split into two parts. [...] The wheel has a straight split [Figure 26]. The crack runs perpendicular to the line of the two mounting holes for the dismantling tool. The crack also runs parallel to the bore for the turbocharger shaft. The blades are all damaged, some of them being worn down to the compressor wheel hub. These heavily worn areas are laterally reversed on the two wheel halves. The rear side of the wheel shows [Figure 27]. It can be seen here clearly that the protruding parts that engage in the claw sleeve for a positive joint have broken out in the middle of the wheel around the shaft bore and are completely absent. The sealing labyrinth on the outer radius of the back of the wheel is relatively heavily worn down but in those areas where the wheel disc is complete still relatively easy to see [...]."<sup>16</sup>*

<sup>16</sup> Ibid., pages 9-10.



Figure 27: Rear of the compressor wheel with sealing labyrinths

*"The wheel's material in the area of the claw is largely broken into small pieces and only partially identifiable [...]. No damage on the claw around the edges and the grooves that would indicate an inadequate fit between the wheel and claw is visible. The fragments available do not indicate whether plastic deformation has occurred during assembly on the protruding parts of the compressor wheel due to the claw."<sup>17</sup>*

*"The extremely heavily damaged blades, which have been worn down to the hub, exhibit plastic deformation and warping of the material. This must have been caused by a transverse (in relation to the direction of the blades) movement, as indicated by the corresponding traces of movement on the materials [Figure 28]. It is reasonable to assume that this occurred after the wheel was split when punching through the diffuser and compressor casing.*



Figure 28: Deformed and broken compressor blades with material smearing

<sup>17</sup> Ibid., page 10.





Figure 29: Broken compressor blades with virtually no deformation

*The two fragments of the compressor wheel can be seen in [Figure 29]. On the slightly more blackened left half it is noticeable that the blade closest to the fracture and its neighbouring blade broke off with only very little deformation. The blades after them (in the direction of rotation) exhibit heavy deformation on the outer end in the direction of rotation. Accordingly, it is reasonable to assume that fragments from preceding blades flew through them. The two blades closest to the fracture do not exhibit any fracture characteristics that could be due to a fracture under heavy deformation in the direction of rotation. Accordingly, it is reasonable to assume that these blades may have suffered fatigue fractures that led to larger blade parts breaking off, which could then have caused the obstruction or further destruction of the wheel. [Figure 30] shows the two discussed blades in question and the two subsequent blades in detail.*



Figure 30: Extract from Figure 29

*It can be clearly seen here that the fracture characteristics on the first and second blade developed largely without deformation, while strong deformations in the direction of rotation with corresponding chips in the material can be seen on the third and fourth*

*blade after the fracture at the upper end, which may have been caused by parts that had broken off of the first and second blades.*

*Both the turbocharger's operating manual and a special service notice (Annex 1) state that a perfect fit between the protruding parts on the back of the compressor wheel and the groove in the claw is essential. If the claw chips a fragment off of the soft aluminium of the compressor wheel and this fragment then migrates into the base of the claw, preventing uniform contact of the claw on the compressor wheel, then the shaft is likely to bend due to the skewed position of the wheel and an imbalance will develop. If this error occurs during final assembly after the rotor has been balanced, then the turbocharger would start operating with this imbalance, having corresponding consequences in terms of fatigue fractures on the shaft and components.*

*Indications of an incorrect fit between the claw and compressor wheel were no longer evident due to the degree of destruction of the components, however."<sup>18</sup>*

### **3.2.6 Additional examinations**

After consulting with the BSU, the expert commissioned Prof. Dr.-Ing. Reinders from the Technology Department (FB1) at Bremerhaven University of Applied Sciences for further material analysis. The statements made in the two corresponding opinions are quoted in the opinion of Prof. Dr.-Ing. Behrens and extracts from them are set out below. The complete opinions are available in German on the BSU's website.

*"The torn off shaft piece with the hydraulic nut and – after the dismantling of the turbocharger – corresponding mating part with serrated teeth were metallographically examined at the Laboratory for Materials Engineering at the Bremerhaven University of Applied Sciences. As the main focus, the fracture surface of the two shaft sections was examined to determine whether a fatigue fracture already existed there as a crack.*

*During the examination (Annexes 2 and 3) it was found that the fracture surface is located exactly at the end of the serration of the turbocharger's shaft on the compressor side. The exact origin of the fracture is at the end of the tapered part of the serration, where a minimal edge on the fragment on the shaft side is also visible. The fracture surface is thus parallel to the turning grooves, which are clearly visible in the area of the transition cone. On the two examined shaft ends it is clearly visible that on one side of the shaft there is a sickle-shaped fatigue fracture surface rotating through about 180°, which has already been hammered considerably. [See also Figure 31.] However, the remainder of the surface of the forced fracture is at least 2/3 of the total cross-sectional area of the shaft at the point of fracture. It is also evident that rather than opening when the shaft bent, the fatigue fracture actually closed.*

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<sup>18</sup> Ibid., pages 10-11.

*It can therefore be assumed that the crack resulting from a fatigue fracture did not cause damage. Since the fatigue fracture surface has been subjected to strong hammering, it is no longer possible to detect the location of the start of the fracture.*

*The hydraulic nut that held the entire compressor wheel-shaft assembly together is still firmly seated on the shaft and the lock nut is tight. Both nuts exhibit mechanical damage but this most probably happened when the damage occurred. Similarly, slight traces of rust can also be seen on the parts but these could be due to the use of the firefighting water. It is also possible that the corrosion marks were caused by the effects of water when the compressor was cleaned. Various metal smear marks, probably aluminium, can be seen on the body of the shaft but they may also have formed when the damage occurred."*<sup>19</sup>

### **3.2.7 Other findings**

In the written statements it was reported that no maintenance work had been carried out directly on the turbocharger beforehand. Only the charging air cooler had been washed in Drammen and 14 days earlier the engine room's crew had changed part of the air filter (the filter mat).

### **3.2.8 Crew**

The Philippine master began his career after graduating from the Philippine Marine School in 1990 as a cadet. He was promoted to third deck officer in 1995, second deck officer in 1997 and chief officer in 2001. He has held an unrestricted certificate of proficiency for masters since 2007. He has mainly served on containers and ro-ro ships. He was employed by this owner since 2014. He had served on the BALTIC BREEZE since 2016. The current deployment started on 7 October 2018.

The 2<sup>nd</sup> engineer is a citizen of Myanmar and holds a degree from the Institute of Marine Technology. After graduating in 2005 he started working on ships as a cadet in 2006. He was promoted to 4<sup>th</sup> engineer in 2010, 3<sup>rd</sup> engineer in 2012 and 2<sup>nd</sup> engineer in 2016. He was employed by this owner since 2017 and has worked mainly on car carriers. The deployment on the BALTIC BREEZE started on 16 June 2018.

The oiler is also a Philippine national. He started his career as a cadet in 1989 and was subsequently employed as an oiler. He has worked on all kinds of ship. He worked for this owner since 2003. His current contract started on 10 September 2018.

The owner provided the time sheets of the 2<sup>nd</sup> engineer and the oiler. They exhibited no anomalies in terms of a risk of fatigue.

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<sup>19</sup> Ibid., pages 11-12.

## 4 ANALYSIS

### 4.1 Damage to the turbocharger

Within the framework of the opinion the BSU's expert drew the following conclusions from the findings made.

*"The speed reduction was initiated because the ship was located south of Heligoland and planned to pick up the pilot at the Elbe buoy. This required a reduction in the speed of the ship. The reduction in engine power is made by the automation system, which reduces the engine speed by 2 rpm each minute. This slow speed reduction can in no way have been the cause of the two surge strokes. Surging of the turbocharger is almost unavoidable during a crash-stop of the engine but there should be no surging with such a slow reduction in speed.*

*The existing damage pattern indicates that it was clearly caused by the compressor of the turbocharger. The damage in the area of the exhaust turbine is to be regarded as consequential.*

*Surging of the turbocharger compressor means that the flow in the compressor must have been disturbed. This can be caused externally, e.g. by a sharp reduction in the flow of air through or by a sharp change in the speed of the compressor.*

*No indications of a significant reduction in the flow of air through the compressor by subsequent throttling could be found. An inspection of the charging air cooler revealed that it was not obstructed in any significant way. Although debris was found on the stator lamination of the charging air cooler [Figure 20], it is unlikely to have resulted in a reduction in flow rate needed for surging.*

*An increase in air temperature after the charging air cooler would have a similar effect. This would also reduce the flow rate through the compressor and the operating point would shift toward the surging limit. The first alarm message registered was a scavenge trunk fire, which may have caused such a heat increase. Since the time of the damage cannot be more closely defined, it is not possible to determine whether the temperature increase in the scavenge trunk or the destruction of the compressor occurred first. In the latter case, the temperature increase could be explained by exhaust gas backflow. However, the temperature increase in the scavenge trunk should also have triggered an audible alarm. On the other hand, the 2<sup>nd</sup> engineer explained when asked that an irregularity reportedly was first noticed due to the surging strokes."<sup>20</sup>*

By contrast, the oiler said in his written statement that he first heard an alarm and then returned to the ECR. The written statements were still not available when the ship was surveyed, however. The expert's comments below therefore relate to the level of knowledge available at that time.

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<sup>20</sup> Ibid., pages 12-13.

*"If the 2<sup>nd</sup> engineer's statement on the chronological sequence is incorrect, then it would also be conceivable that a breakage occurred during surging due to the increased vibratory load on the compressor blades. However, the blades can normally withstand short-term surging. The change in speed occurring during surging would not be sufficient to cause this damage.*

*Another possible cause for the surging is a change in the geometry of the blades. This is usually only possible due to damage.*

*In the area of the inner side of the air filter as well as the air inlet guide and elements attached to it, such as the speed sensor cover, no damage that may have caused additional harm to the compressor blades was detected, however.*

*A disturbance of the inlet flow into the compressor wheel can also trigger surging.*

*Since the explosion of the turbocharger occurred immediately after the surging strokes, it can be assumed that damage in any form whatsoever to the compressor blades led to the damage in question.*

*It is therefore highly probable that one of the compressor blades broke and the fragment caused the further damage. As already commented on above, a fracture surface which shows no significant deformation is conspicuous on two blades near the compressor wheel's fracture surface. However, the outer area of adjacent blades is heavily deformed in the direction of rotation and material parts have 'shot out' there, which fragments of the preceding blade may have caused. The second blade next to the fracture [Figure 30] is broken near the base, meaning this may have resulted in relatively large fragments. The absence of the blades could also explain the surge strokes, as this disturbed the flow in the compressor wheel significantly.*

*Since the engine was still running at about [103] revolutions (or almost full load) when the damage occurred, the kinetic energy that had built up in the turbocharger's rotor was quite considerable – given the turbocharger's speed was also probably still close to the maximum speed, i.e. in the range of about 11,000-12,000 revolutions. Accordingly, the actual course of the damage could have been such that one or two blade(s) of the compressor wheel break off due to a fatigue fracture and disintegrate(s) into relatively large pieces. These damage the subsequent blades and get jammed between the compressor wheel and the compressor casing. This causes the rotor shaft to bend and the compressor wheel to rub against the labyrinths, which are levelled all around because of this. This means that the compressor must have made at least one more revolution with the complete compressor wheel. At some point during this process the debris from the blades of the compressor wheel blocks it mechanically, causing the wheel to break into two parts in the plane of the compressor shaft because of the high kinetic energy in the rotor due to the high speed.*

*It is possible that a notch had already formed in the hub of the compressor wheel when the blades broke, meaning that the position of the fracture was predetermined because the blades that could potentially have broken off are directly adjacent to the fracture plane. The two sections of the compressor wheel are thrown outwards by the centrifugal forces and penetrate the compressor casing and the spiral of the turbocharger. These components are broken down into small pieces in the process.*

*It is not possible to pinpoint the exact time at which the shaft broke off but it can be assumed that it was early on in the damage sequence, possibly even before the wheel broke apart. Since the shaft was bent by about 15-20°, it must have been intact at the time of the damage, otherwise no more forces could have been acting to bend it.*

*As the examinations of the Laboratory for Materials Science at the Bremerhaven University of Applied Sciences show, the shaft had a crack in the form of a fatigue fracture, which was already smoothed on its surface, i.e. it must have been in operation for a long time.*

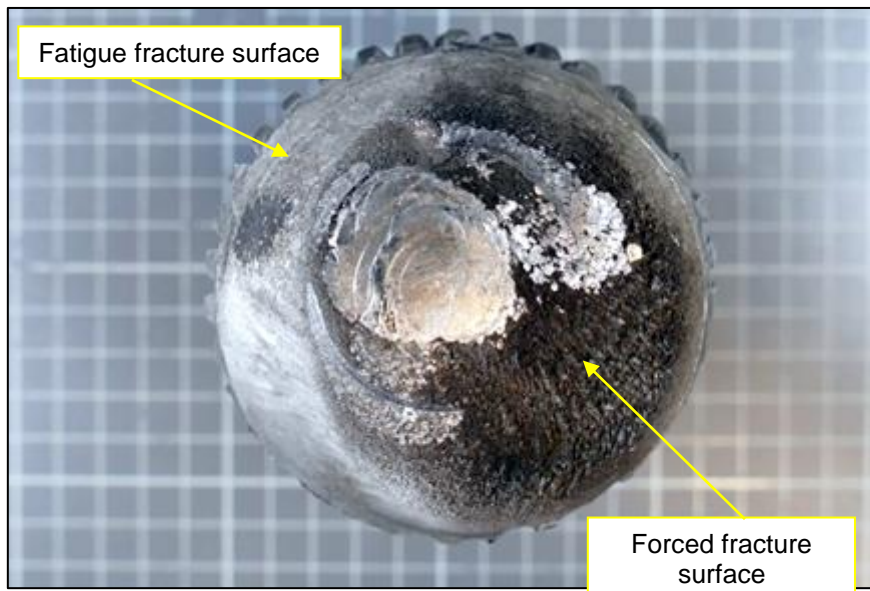


Figure 31: Fracture surface of the rotor shaft with fatigue and forced fractures<sup>21</sup>

*However, it is highly unlikely that this crack was responsible for the fracture because the bend in the shaft caused the crack to close rather than open. The reduction in cross-sectional surface by about 30% near the fracture surface is likely to have facilitated a tearing off of the shaft end in the event of excessive loading due to the blocking of the compressor wheel, as the stresses in the shaft reached a critical level more quickly because of the reduction in cross-sectional surface. It is no longer possible to clearly determine the cause of the fatigue fracture retrospectively. The metallographic examinations show that the fracture occurred parallel to machining grooves on the shaft, i.e. it is possible that an increased notch effect could have occurred there due to insufficient surface quality during machining. The fracture on the shaft is indicative of rotating bending, which is a typical overload due to imbalance. It*

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<sup>21</sup> Figure from Prof. Dr.-Ing. Reinders: Examination of the fracture surface of a MET 66SC turbocharger from the MV Baltic Breeze – Part 2. 2019, page 4.

*is also possible that during the most recent assembly of the compressor wheel the claw (which creates a positive joint between the shaft and compressor wheel) chipped a fragment off of the compressor wheel recess, which then jammed between the claw and compressor wheel and caused the shaft to skew and slightly bend. This process is described in the turbocharger's manual and in a service notice from the turbocharger's manufacturer and should be avoided at all costs, as otherwise the shaft could be bent with correspondingly higher loads in the critical area. No traces of such a process could be found on the fragments of the compressor wheel or on the claw, however.*

*Since the engine was still running at an extremely high power output when the damage occurred, the exhaust energy fed to the exhaust turbine was also correspondingly high. After the compressor shaft had been torn off, a load moment for the turbine no longer existed, meaning the remaining rotor, i.e. the shaft and exhaust turbine, speeded up out of control due to the exhaust energy supply. This overspeed must have reached such levels as to cause the turbine blades to tear off due to the centrifugal forces, as already mentioned. The damage to the turbine blades must clearly be classed as consequential.*

*The complete destruction of the lower part of the bearing block on the compressor side, the separation of the turbine casing from the bearing housing, the crack formation in the part of the bearing housing on the turbine side, and the fracturing of the turbocharger base show that immense radial forces must have been acting when the turbocharger was destroyed.*

*The traces of damage on the rear wall of the compressor, especially around the sealing labyrinth, and the damage to the diffuser ring indicate that the two halves of the compressor wheel moved out of their position horizontally and penetrated the compressor casing and the surrounding areas. The location of the wheel halves has already been commented on. This is of course influenced by the trajectory of the debris and impact thereof on engine room components. However, it is no longer possible to make a statement on this because of the high degree of destruction in the engine room.*

*In summary, it can be stated that it is highly probable that a fatigue fracture on one or several compressor blades triggered the damage event. It is no longer possible to determine whether the fracture was caused by fatigue, material creep or an earlier short-term overload. It is also not known whether the manufacturer's service life information for the turbocharger's components take individual operating conditions into account, as is the case with a competitor.*

*Other damage to the turbocharger and the engine, as well as to the engine room should be regarded as consequential."*<sup>22</sup>

*"The appearance of the damaged area (especially the rear wall of the compressor and the bearing area of the turbocharger) suggests that after the turbocharger shaft was torn off and the compressor casing was destroyed, lubricating oil leaked from the bearing of the turbocharger and ignited due to fragments heated by the fracture. According to the operating manual, the oil flows through the bearings at [...] about 130 l/min. This means that while the fire was burning and up until the oil pumps were switched off, it must be assumed that about 30-50 l of lubricating oil could have been burnt."*<sup>23</sup>

#### **4.2 Firefighting by the crew**

The 2<sup>nd</sup> engineer immediately responded to the outbreak of the fire by activating the HI-FOG fire extinguishing system, which was also installed in the area of the turbocharger platform.

This and the actuation of the quick-closing valves for the main engine led to the fire extinguishing rapidly, since no further oil was transported to the turbocharger, which could have burnt there, when the main engine came to a standstill.

The crew of the BALTIC BREEZE established watertight integrity in the course of the initial measures. Due to the heavy smoke, it was initially not possible to advance into the engine room. Accordingly, statements on the situation in the engine room could not be made at the beginning.

All in all, the investigators believe in hindsight that the crew's actions were well coordinated and methodical. The crew extinguished the fire by the means at their disposal. The VTS was informed about the development on board at all times.

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<sup>22</sup> Ibid., pages 13-16.

<sup>23</sup> Ibid., page 5.



## 5 CONCLUSIONS

The expert's examination identified five possible causes for the destruction of the BALTIC BREEZE's turbocharger:

1. A considerable change in the speed of the main engine within a short period.
2. The obstruction of the charging air cooler and associated disturbance of the flow through this component.
3. A change in the geometry of the blades on the compressor wheel due to a foreign object and associated disturbance of the inlet flow.
4. A change in air resistance after the compressor wheel due to fire in the scavenge trunk.
5. A change in the geometry of the blades due to damage to the actual compressor wheel and associated disturbance of the inlet flow.

It should be noted in principle that the lack of data on the main engine's operating conditions complicated the investigation. This also made it impossible to correlate alarms recorded by the alarm log with operating conditions, although it should be noted that such data collection is rather unusual for ships of this age.

The probability of one of the above causes leading to the triggering of the damage is discussed below:

Re 1. The examination indicates that there was no significant change in the main engine's speed shortly after the start of the automatic reduction. Although no technical recordings are available, it is assumed that the crew of the engine room would have noticed such a change.

Re 2. The inspection of the charging air cooler did not provide any evidence for this assumption.

Re 3. An inspection of the air filter and the air inlet guide yielded no evidence that any of these components detached from them and were subsequently sucked in, damaging the blades of the compressor wheel.

Re 4. It is likely that the first event was the fire in the scavenge trunk. The oiler's statement at least indicates this. The fire then caused the turbocharger to surge. A turbocharger is designed so that it can usually withstand surging without damage. Based on the evidence of existing damage to one or more compressor blade(s), surging may have caused an overload on these blades. This overload then led to the compressor blades breaking and finally to the complete loss of the turbocharger.

A possible cause of the fire in the scavenge trunk could not be determined during this investigation.

Re 5. It is equally probable that the primary event was a fatigue fracture on one or several compressor blades due to reaching the durability limit, i.e. without external influence. The sudden drop in output in the wake of the damage triggered the backflow, which then led to the surging of the turbocharger. Immediately afterwards the turbocharger was destroyed in the manner described.

During the investigation it could not be determined with certainty whether the damage to the turbocharger shaft (the fatigue fracture) detected in the Laboratory for Materials Science caused the shaft to run untrue and was thus possibly the cause of the earlier damage to the compressor blades.

The investigation found no evidence to suggest that incorrect/poor handling or faulty maintenance of the turbocharger by the crew led to earlier damage that facilitated its destruction. This finding also applies to the performance of the last works on the turbocharger by the service company.

Since the investigation has not identified a clear cause of the accident, this report does not contain any safety recommendations.

## **6 SOURCES**

- Investigations of the Federal Police
- Incident log of the MERAC
- Report file of VTS German Bight
- Situation reports of WSP Brunsbüttel
- Report (with fire report) of Cuxhaven Police Service
- Mission report of Cuxhaven Fire Service
- Ship documents from the BALTIC BREEZE
- Manufacturer's manual for the turbocharger
- Written explanations/submissions by crew members of the BALTIC BREEZE
- Expert opinion of Prof. Dr.-Ing. Behrens and the related expert opinion of Prof. Dr.-Ing. Reinders
- Navigational chart of the BSH
- Figures (if not specified in the actual figure):
  - BSU: Figures 1, 6-11, 13-15, 17, 19-24
  - Opinion on engine damage: Figures 16, 18, 25-30
  - Opinion on materials examination: Figure 31

## **7 ANNEXES**

This report only contains extracts of the expert opinions prepared in connection with the investigation. The main opinion with all annexes is available in German on the website of the Federal Maritime Casualty Investigation Bureau ([www.bsu-bund.de](http://www.bsu-bund.de)).