MAN inspection report

Investigation Report

Material Laboratory Augsburg

PEQAM 18 / 1526

Field failure: DFDS Finlandia Seaways; 12V 48/60; fracture of connecting rod head (PSHR-2018-008)

Distribution		Requested by		Report	
		Name	[redacted]	Date request	23.05.2018
		Dept.	SEAATM	Date report	19.07.2018
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1. Background / Task

On 16 April 2018 the aforementioned vessel suffered the total loss of the main engine in combination with flown out engine parts and fire in the engine room. An inspection after engine stop and extinguished fire revealed the mainly affected cylinders were A5 and B5. During RCA on board of the vessel it was decided to send the connecting rod heads of A5 and B5 to MAN in Augsburg for further investigation.

Subject	Connecting rod head
Vessel	Finlandia Seaways
Engine type	12V 48/60
Engine number	1135079
Component operating hours	A5: 110000 ; B5 approx. 40000-50000
Engine operating hours	110000
Drawing	11.03004-0075
Material	Before 2002: 42CrMo4 After 2002: 34CrNiMo6
Marking	A5: see Pic. 2-4 B5: see Pic. 22-23

The components should be investigated in detail. Furthermore, the mechanical properties should be determined and the connecting rod head B5 should be measured.

2. Summary

Component	Findings
Connecting rod head A5 Pic. 1-21	- The fracture occurred on the exhaust side of the connecting rod just above the top end of the stiffener - On the lower piece both fracture surfaces and the bearing surface were found heavily damaged and/ or completely destroyed ⟶ no investigation possible - On the upper piece the fracture surface of the exhaust side showed signs of fatigue crack propagation (beach marks) - The exact position of crack initiation site could not be determined (due to damage) - The fracture surface on the control side was found heavily damaged ⟶ no investigation possible - The microsection showed a quenched and tempered microstructure. - The materials strength was partly in accordance with the specification (table 1). - The ductility of the material was not in accordance with the specification (table 1); a microsection through the tensile specimen A5 trans No.2 showed an aggregation of non-metallic inclusions which was often observed on the specimen - The chemical composition do not fully correspond with the material specification of 42CrMo4 mod (table 2)
Connecting rod head B5 Pic. 22-28	- Connecting rod head ruptured from connecting rod - Component suffered many impact damage - Crack testing after disassembling the bearing bush revealed no cracks - The bearing surface showed slight contact and friction marks; however no fretting was observed - The microsection showed a uniform, fine grained, quenched and tempered microstructure - The mechanical properties were in accordance with the specification (table 1)

Processed	Reviewed	Approved
PEQAM– [redacted]	PEQAME – [redacted]	PEQAM – [redacted]

	- The chemical composition corresponds to the specification of 34CrNiMo6 mod (table 2) - The diameter of the bore was in accordance with the specification (table 3) - The roundness of the bore was very slight above the specified value which indicate a slight ovality in longitudinal direction of the connecting rod (table 3)
Bearing bush B5 Pic. 29-31	- The bearing bush showed a normal wear pattern - On the backside several friction marks were observed; the friction marks correspond with the observed spots on the bearing surface of the connecting rod head - The friction marks are not considered as fretting

3. Conclusion

The fracture of the connecting rod head A5 was caused by a fatigue crack. Due to the heavy damage of the component, the exact position of the fatigue crack initiation could not be determined.
Although the material of the connecting rod head A5 did not fully correspond with the modified material specification of MAN and the mechanical properties do not meet the specification, these deviations were not the root cause for the failure.
The mechanical properties, the microstructure and the chemical composition of the connecting rod B5 were found in accordance with the standard.
A hypothesis regarding the root cause of the fracture is given in the RCA-report.

Statement of the engineering department of MAN regarding the deviations of the mechanical properties:

Fatigue assessment of connecting rods is based on FKM Guideline “ANALYTICAL STRENGTH ASSESSMENT OF COMPONENTS” Made of Steel, Cast Iron and Aluminum Materials in Mechanical Engineering 6th revised Edition, 2012. Here, fatigue strength is determined based on ultimate tensile strength Rm. Taking into account actual values of tensile test (DIN EN 10002) the deviation from the requirements are within the acceptance for single cases (-3% for Rm).
For single cases the acceptance for A5 and Z is -15% for specimen’s static values determined in accordance with Q-guideline Q10.09431-2202 (small eye: axis small eye to big eye). In principal for forged components especially static values A5 and Z are lower in other directions. According to Q-guideline Q10.09431-2202 there is no requirement for static strength for the extraction of specimen for the investigated orientation.

4. Results

Exhaust side EXS

Control side CS

Picture 1:
Connecting rod head A5; lower piece

The fracture of the connecting rod head A5 occurred in the area of the top end of the stiffener. Due to fracture, the component suffered a lot of impact damage. Therefore, a detailed investigation of the component was not possible.

Picture 2:
Connecting rod head A5; marking 1

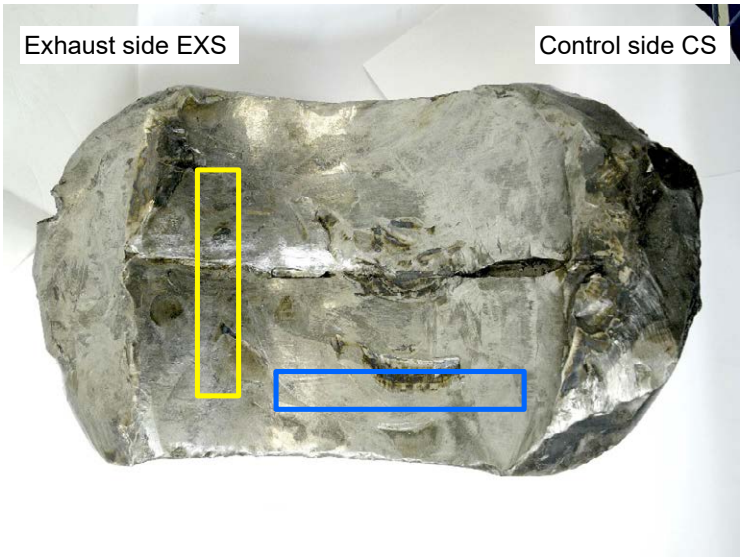
The first imprinted marking of the connecting rod head.

Picture 3:
Connecting rod head A5; lower piece

The second imprinted marking of the connecting rod head.

Picture 4:
Connecting rod head A5; lower piece

The third imprinted marking of the connecting rod head.



Picture 5:
Connecting rod head A5; lower piece

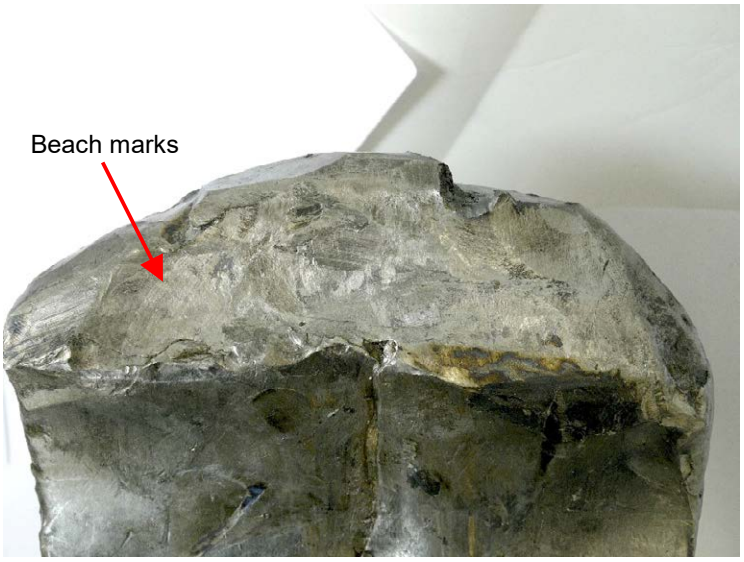
Both fracture surfaces as well as the area of the bearing bush showed heavy impact damage. A detailed investigation of these areas was not possible.

Specimen – longitudinal direction

Specimen – transverse direction

Picture 6:
Connecting rod head A5; fracture surface control side

The fracture surface was found completely destroyed by heavy impacts. Therefore, a detailed investigation was not possible.

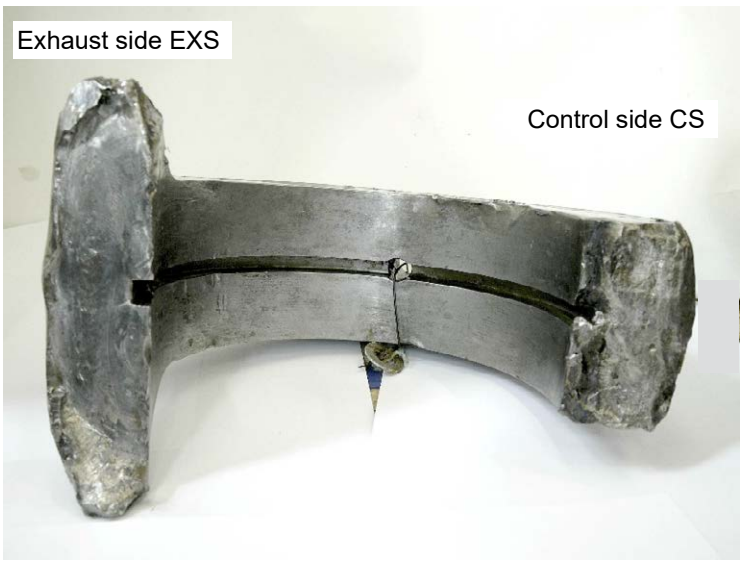


Picture 7:
Connecting rod head A5; fracture surface exhaust side

The fracture surface on the exhaust side also showed heavy impact damage. Only few weak signs of fatigue (beach marks) were visible.

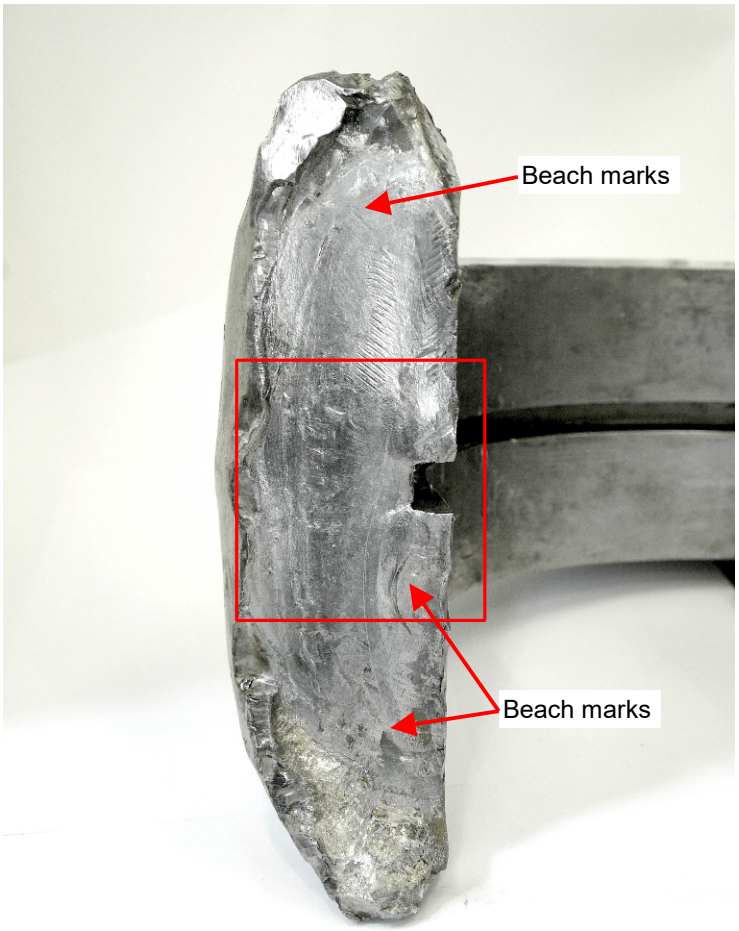
Picture 8:
Connecting rod head A5; upper piece

The broken upper piece of the connecting rod head showed also several impact marks.



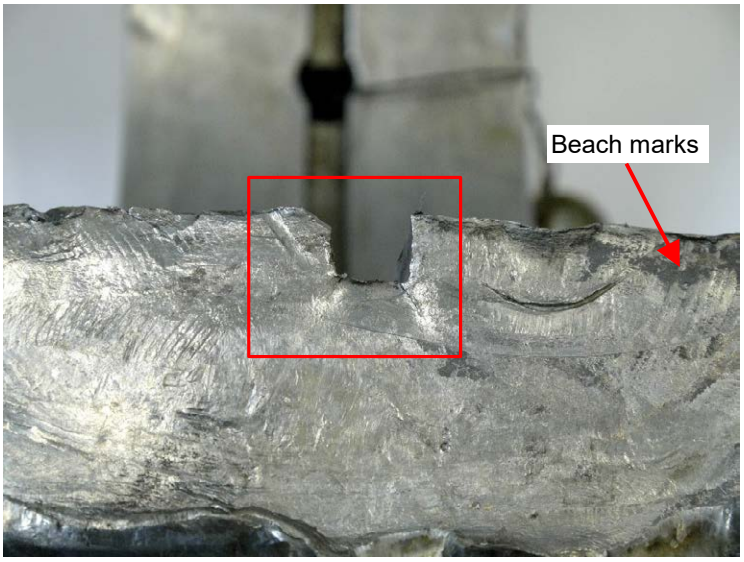
Picture 9:
Connecting rod head A5; upper piece

Both fracture surfaces were found to be heavy damaged. Despite the damage signs of fatigue crack propagation were observed on the fracture surface of the exhaust side. In the bearing area no sign of fretting was observed.



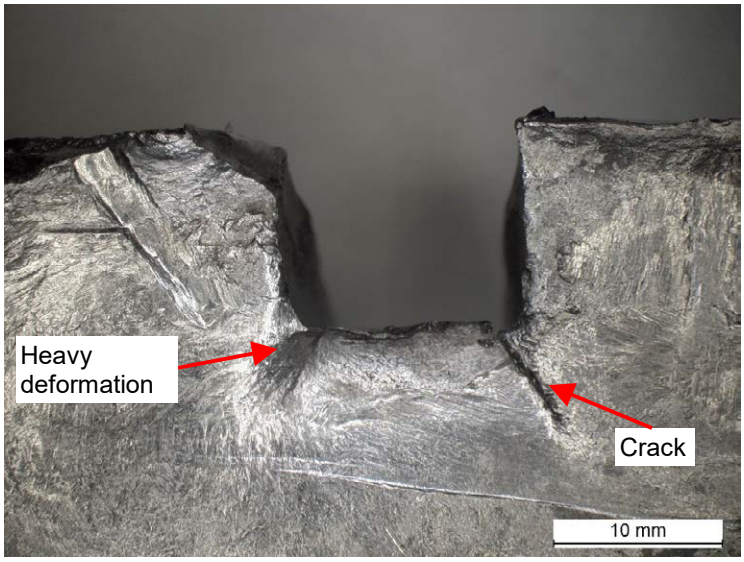
Picture 10:
Connecting rod head A5; fracture surface exhaust side (upper piece)

The fracture surface was also found to be damaged. However, signs of fatigue crack propagation (beach marks) were observed. Based on the location and extension of the fatigue crack it is assumed the crack initiation site is located around the oil channel.



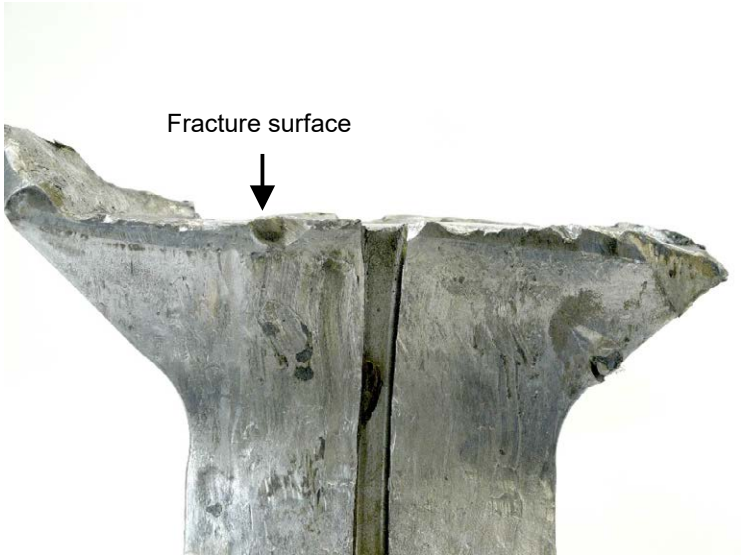
Picture 11:
Connecting rod head A5; fracture surface exhaust side (upper piece)

The fracture surface suffered multiple impacts, therefore no detailed investigation was possible. Unfortunately, the area around the oil channel was also affected by impact damage.



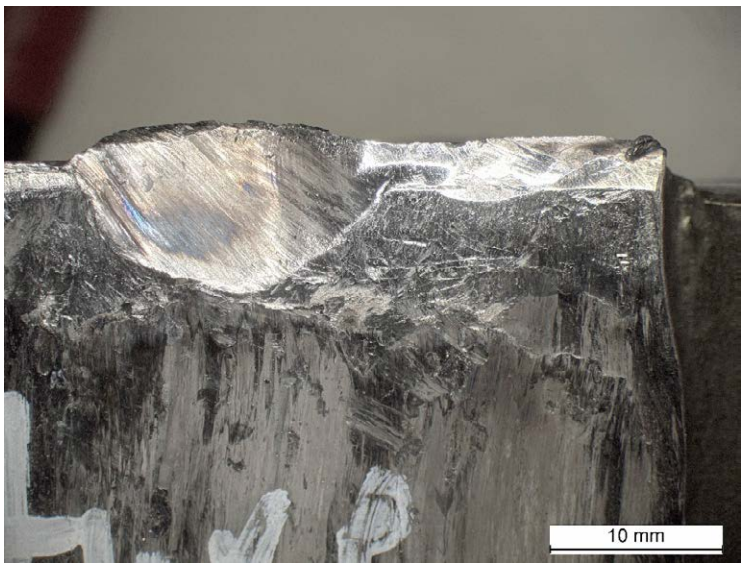
Picture 12:
Connecting rod head A5; fracture surface exhaust side (upper piece)

The fracture surface around the oil channel was found cracked and deformed. The exact position of the crack initiation site could not be determined.



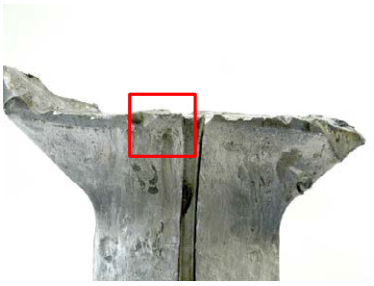
Picture 13:
Connecting rod head A5; bearing surface exhaust side (upper piece)

The bearing surface showed impact damage and deformation, especially at the edge of the fracture surface.



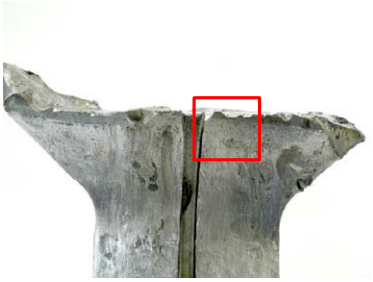
Picture 14:
Connecting rod head A5; bearing surface exhaust side (upper piece)

The bearing surface showed impact damage and deformation at the edge of the fracture surface. No investigation regarding fatigue crack initiation was possible.



Picture 15:
Connecting rod head A5; bearing surface exhaust side (upper piece)

On the opposite side of the oil channel similar damage is visible.

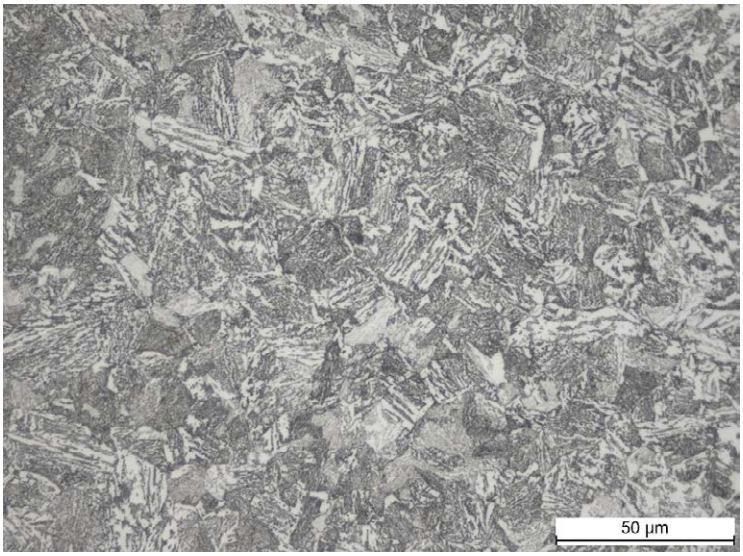


Picture 16:
Connecting rod head A5; fracture surface control side (upper piece)

The opposite fracture surface also showed heavy impact damage. Therefore, no further investigation was possible.

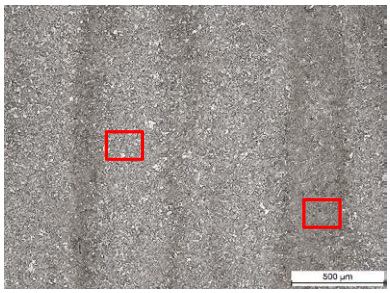
Picture 17:
Connecting rod head A5; bearing surface control side (upper piece)

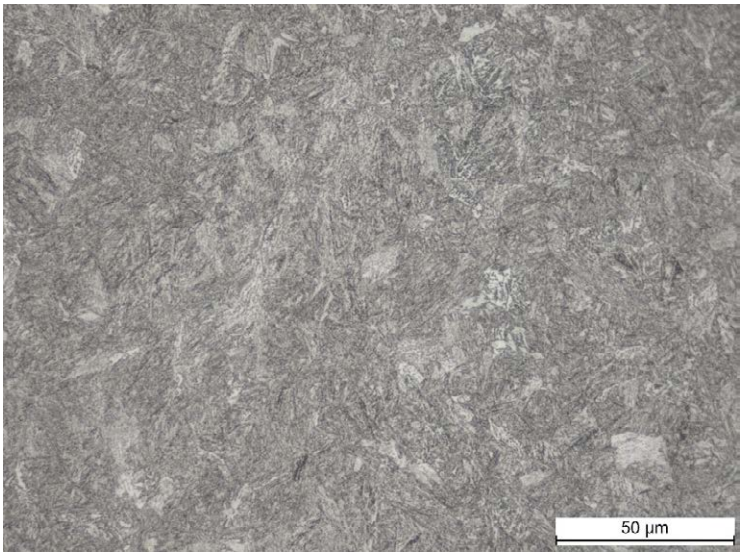
The bearing surface showed heavy impact damage and deformation. Especially the edge of the fracture surface was found destroyed completely.



Picture 18:
Connecting rod head A5; microsection (bright area)

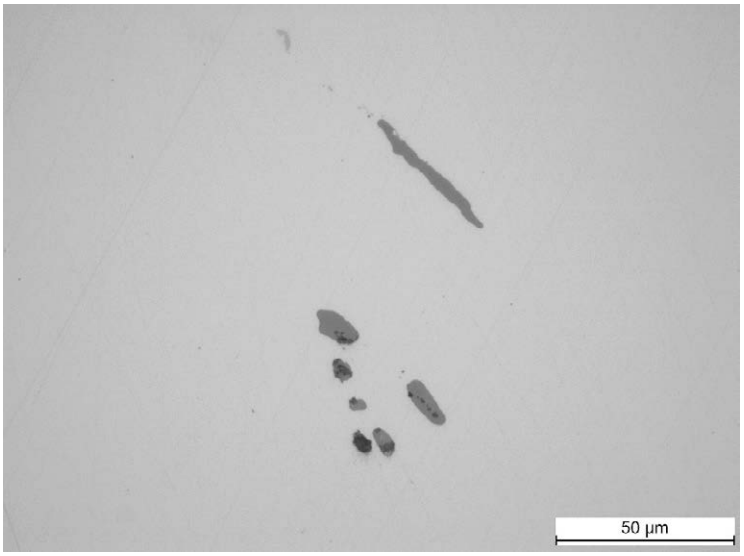
The microsection showed a quenched and tempered microstructure.





Picture 19:
Connecting rod head A5; microsection (dark area)

The microsection showed a quenched and tempered microstructure.



Picture 20:
Tensile Specimen A5 – trans No. 2; microsection

The microsection showed many aggregations of non-metallic inclusions. The increased occurrence of such aggregations can reduce the ductility of the material.

Picture 21:
Connecting rod head B5

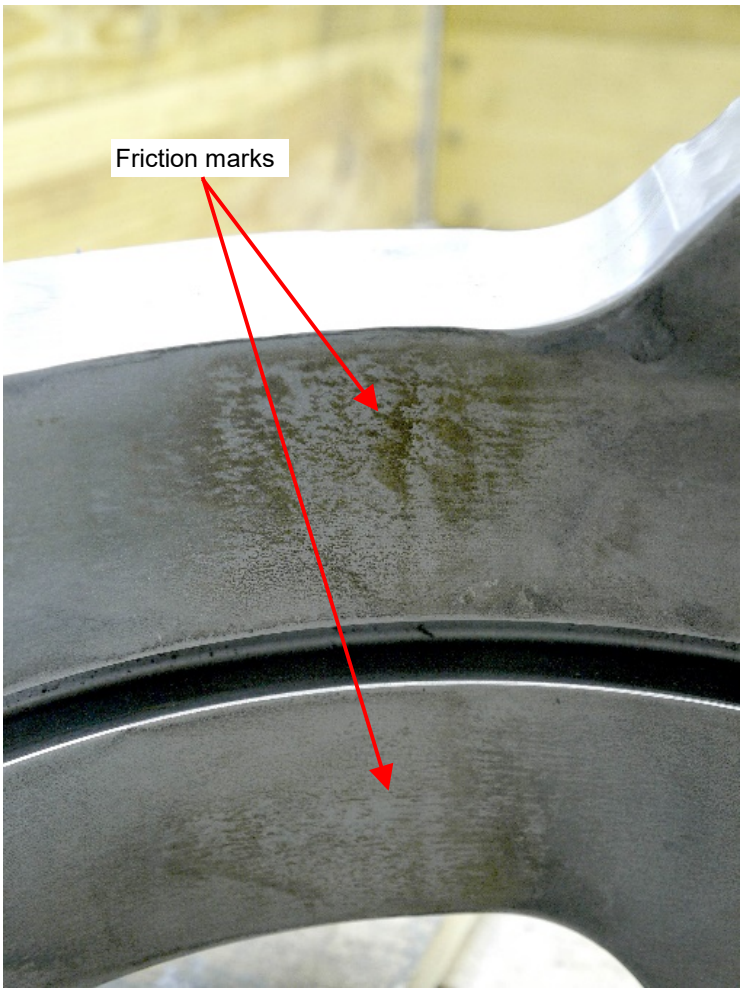
The connecting rod head B5 suffered multiple impact damage. After disassembling the bearing bush the connecting rod head was measured regarding diameter and roundness of the bore. Furthermore, a magnetic crack testing was carried out. No cracks were detected.

Picture 22:
Connecting rod head B5; marking 1

The first imprinted marking of the connecting rod head B5.

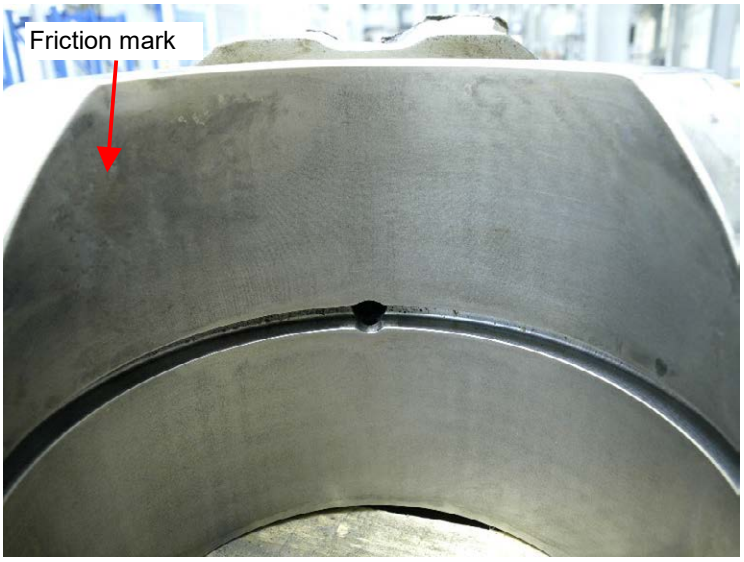
Picture 23:
Connecting rod head B5; marking 2

The second imprinted marking of the connecting rod head B5.



Picture 24:
Connecting rod head B5; bearing surface

On the bearing surface slight signs of friction between connecting rod head and bearing bush were visible. The friction marks were not considered as fretting. A magnetic crack testing in this area revealed no cracks.

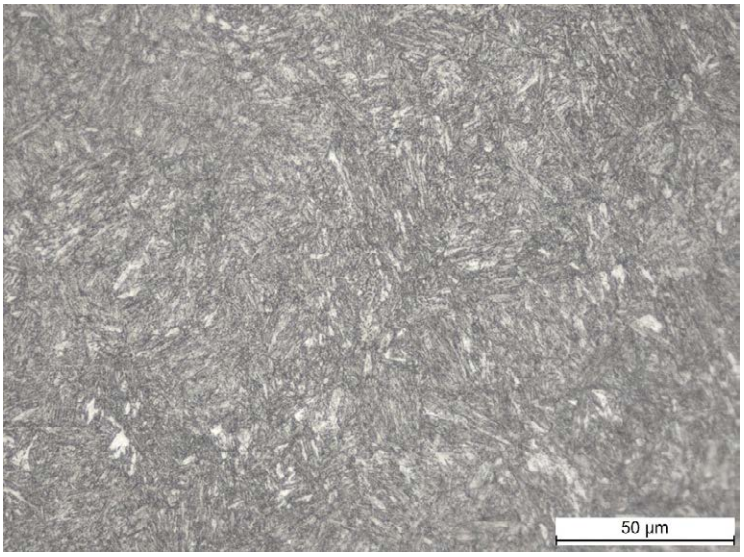


Picture 25:
Connecting rod head B5; bearing surface

On the bearing surface slight signs of friction between connecting rod head and bearing bush were visible. The friction marks were not considered as fretting. A magnetic crack testing in this area revealed no cracks.

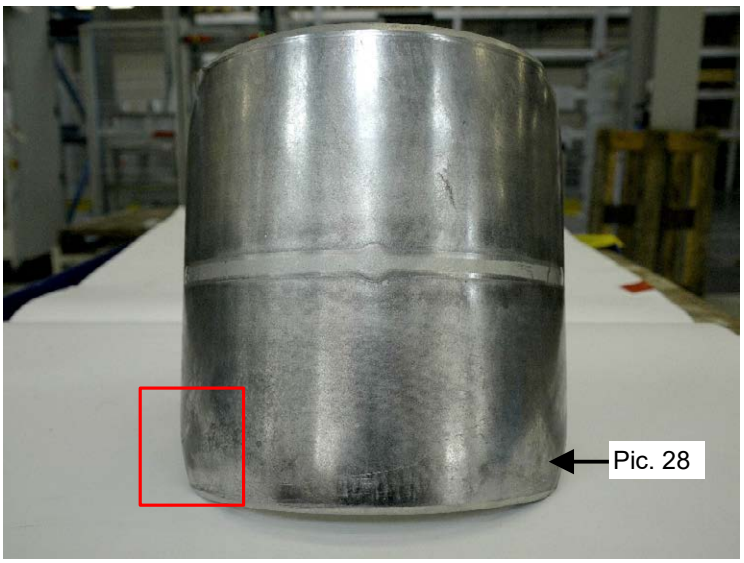
Picture 26:
Connecting rod head B5; bearing surface

On the bearing surface slight signs of friction between connecting rod head and bearing bush were visible. The friction marks were not considered as fretting. A magnetic crack testing in this area revealed no cracks.



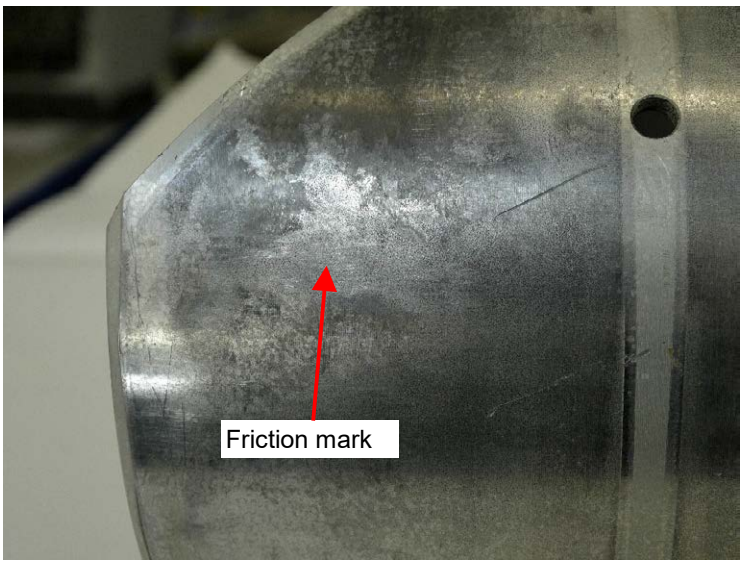
Picture 27:
Connecting rod head A5; microsection

The microsection showed a uniform, fine grained, quenched and tempered microstructure.



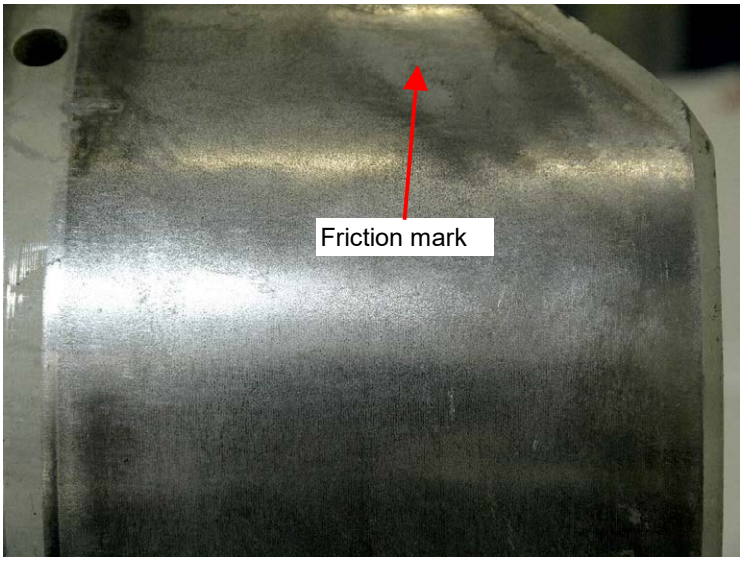
Picture 28:
Bearing bush B5; backside

The condition of the backside corresponds to the bearing surface of the connecting rod head. At several positions friction marks were observed.



Picture 29:
Bearing bush B5; backside

On the backside several friction marks were observed. These spots were not considered as fretting.



Picture 30:
Bearing bush B5; backside

On the backside several friction marks were observed. These spots were not considered as fretting.

Value	Measured			
	A5 – long.	A5 – trans.	B5 – long.	B5 – trans.
Yield strength $R_{p0,2}$	761 N/mm² 815 N/mm²	824 N/mm² 846 N/mm²	822 N/mm² 829 N/mm²	836 N/mm² 826 N/mm²
Tensile strength R_m	897 N/mm² 949 N/mm²	941 N/mm² 947 N/mm²	964 N/mm² 968 N/mm²	975 N/mm² 965 N/mm²
Elongation at fracture A_5	11,9 % 10,6 %	11,7 % 7,2 %	15,7 % 16,7 %	15,0 % 14,3 %
Reduction area at fracture Z	52 % 55 %	42 % 44 %	54 % 55 %	49 % 49 %
Notch impact strength KV	42 J, 65 J, 55 J	41 J, 53 J, 46 J	81 J, 77 J, 79 J	92 J, 90 J, 86 J

Table 1: Results of Tension tests and Charpy tests

Element	34CrNiMo6 Melt analysis in acc. with DIN EN 10083-3	42CrMo4mod Melt analysis in acc. with DIN EN 10083-3	Piece analysis deviation in acc. with DIN 10083-3	Measured	
				A5	B5
C	0.30 - 0.38	0.38 - 0.45	± 0.02	0.42	0.35
Si	0.00 - 0.40	0.00 - 0.40	+ 0.03	0.29	0.18
Mn	0.50 - 0.80	0.60 - 0.90	± 0.04	0.82	0.67
P	0.000 - 0.025	0.000 - 0.025	+ 0.005	0.011	0.010
S	0.000 - 0.035	0.000 - 0.035	+ 0.005	0.009	0.011
Cr	1.30 - 1.70	1.30 - 1.70	± 0.05	1.07	1.64
Ni	1.30 - 1.70	0.40 - 0.50	± 0.05	0.11	1.65
Mo	0.15 - 0.30	---		0.22	0.26

Table 2: Results of chemical analysis of connecting rod heads

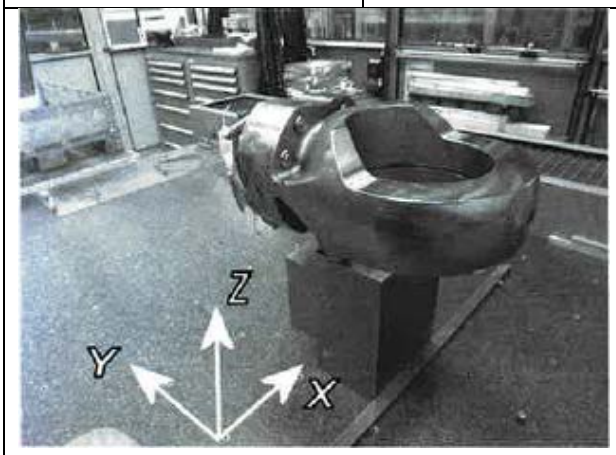
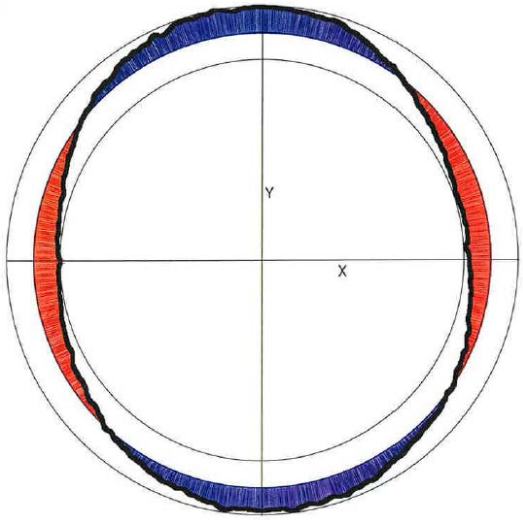
Value	Specified	Measured
Diameter of bore	244 H6 (244.000 – 244.029 mm)	Z=-6.5 244.013 mm Z=-40.0 244.013 mm Z=-71.5 244.013 mm Z=-106.5 244.013 mm
Roundness of bore	Deviation < 0.020 mm	Z=-6.5 0.029 mm Z=-40.0 0.031 mm Z=-71.5 0.041 mm Z=-106.5 0.032 mm
		

Table 3: Results of measurement of connecting rod head B5

MAN customer information no. 344/2015

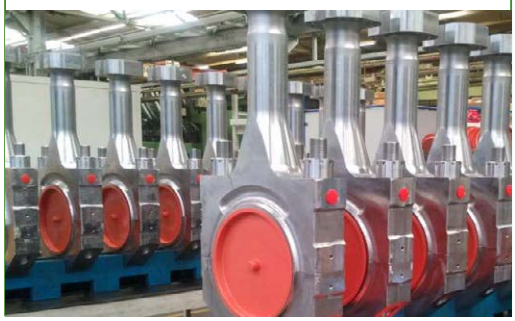
Action Code:
When convenient

Lifetime of Connecting Rods

PrimeServ Customer Information
No. 344 / April 2015

Concerns
MAN Diesel & Turbo four-stroke engines:
V28/33D, L+V32/40, L+V32/40CD,
L+V32/44CR, V35/44G, L+V40/45,
L+V40/54B, L+V52/55, L+V48/60,
L+V48/60B, L+V51/60DF, L58/64

Filing Advice
Assembly group / work card 030



Occasion

Our medium-speed engine types are successfully used in ships and power plants worldwide. There are engines which have been in service as long as 25 years or more. Many of these engines have already reached more than 100,000 operating hours.

During their operation, diesel engines are subjected to certain stress which inevitably leads to aging and wear. This also applies to the connection rods.

Experience

Field experience and measurements have shown that the maximum ovality value of the big end bearing bore is reached at a component operating time of approximately 100,000 running hours.

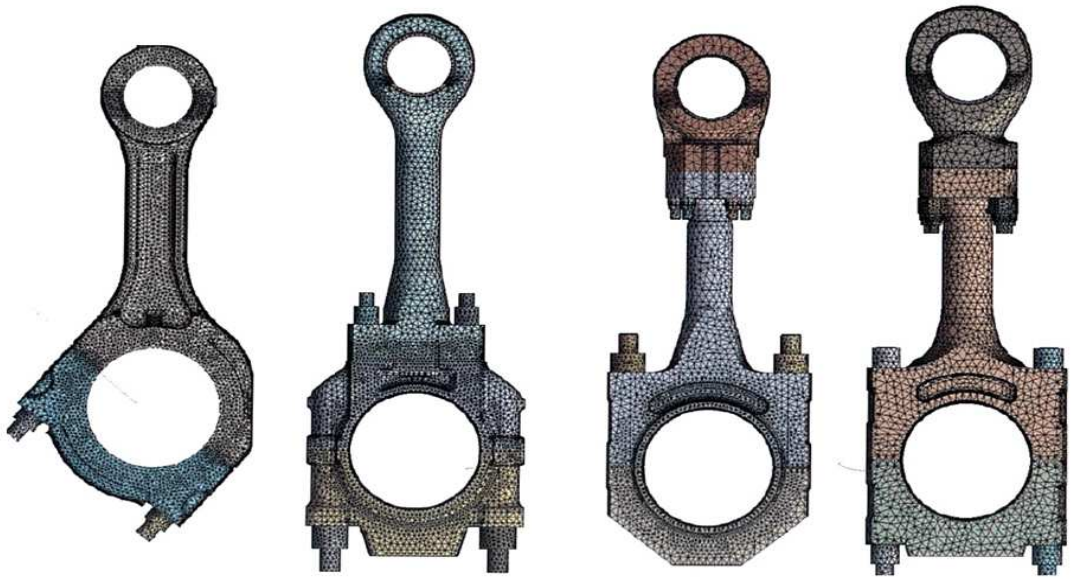
Relative movements between the contact surface and the bearing can either cause a plastic deformation of the big end bearing bore directly, or the ovality value can be exceeded due to fretting and several reworks according to our PrimeServ Customer Information “Fretting at Conrod Bearings” (CUS275).

MAN Diesel & Turbo SE
Head office (& postal address)
Stadtbachstraße 1
86153 Augsburg
Germany
Phone: +49 (0) 821 322 0
Fax: +49 (0) 821 322 3382
mandiesel-de@mandieselturbo.com
www.mandieselturbo.com

PrimeServ
After Sales Augsburg
Stadtbachstraße 1
86153 Augsburg
Germany
Phone: +49 (0) 821 322 3509
Fax: +49 (0) 821 322 1530
primeserv-aug@mandieselturbo.com

PrimeServ
After Sales Technical
Stadtbachstraße 1
86153 Augsburg
Germany
Phone: +49 (0) 821 322 1499 (24-h-hotline)
Fax: +49 (0) 821 322 3838
primeserv-aug-technical@mandieselturbo.com

PrimeServ
After Sales Commercial
Stadtbachstraße 1
86153 Augsburg
Germany
Phone: +49 (0) 821 322 1799 (24-h-hotline)
Fax: +49 (0) 821 322 3574
primeserv-aug-commercial@mandieselturbo.com



Recommendation

Please note that the ovality measurments can only be taken with completely assembled and tightened connecting rods (big end bearing body and conrod depending on engine type). If the maximum value is exceeded, we recommend to refurbish the conrod in one of our PrimeServ workshops. Below please find the maximal permitted values for ovality.

Engine types	Max. operating lifetime ovality
V28/33D, L+V32/40, L+V32/40CD, L+V32/44CR, V35/44G L+V40/45, L40/54B, L+V48/60, L+V48/60B L52/55, L+V51/60DF, L58/64	0.04 mm
V52/55	0.02 mm

Furthermore we recommend to exchange the connecting rods latest at 100,000 running hours by new ones.

Contact

Should you have any queries, our Technical Service will be pleased to be of assistance:

MAN Diesel & Turbo SE
86224 Augsburg
Tel.: +49 (0) 821 322-4063
Fax: +49 (0) 821 322-3838
E-mail: primeserv-aug-technical@mandieselturbo.com

[redacted]

[redacted]
Vice President
After Sales

[redacted]
Senior Manager
After Sales Technical

Please forward this information to your technical operating personnel and remember to inform us of the current operating hours of your MAN Diesel & Turbo engines.

The Test House (Cambridge) Ltd metallurgical report

LABORATORY REPORT

LABORATORY BASED EXAMINATION OF A FAILED CON-ROD SMALL END IN COMPARISON WITH TWO SMALL END CON-RODS ON BOARD RO-RO CARGO VESSEL FINLANDIA SEAWAYS

For: MAIB
1st Floor Spring Place
105 Commercial Road
Southampton
SO15 1GH

THE TEST HOUSE (CAMBRIDGE) LTD REPORT REFERENCE: T81515
PURCHASE ORDER No. MAIB18023
RECEIPT DATE: 4 December 2018 (Instructions)
REPORT DATE: 21 May 2019

1. INTRODUCTION

The Test House was provided with a failed, a sectioned and intact connecting rod small ends from the 12 cylinder MAN medium speed diesel main engine of a RO-RO cargo vessel FINLANDIA SEAWAYS (Figure 1). The vessel suffered a catastrophic engine failure due to a failed connecting rod small end with consequential debris thrown through the crank case entablature into the engine room causing a fire.

MAIB wanted to know if the cause of failure was material related and the engine was examined in The Test House (TTH) metallurgical laboratory as follows.

2. RECEIPT INSPECTION & EXAMINATION

The crate comprised of a failed, a sectioned and an intact connecting rod small end along with a shell bearing and boxed remnants of the small ends (Figure 2). The shell bearing showed signs of post failure damage (Figures 3 to 5). The A5 connecting rod small end comprised of a fractured small end with distinct

identification marks and cut sections boxed separately (Figures 6 to 15). The fracture surface showed a flat/featureless surface, clear evidence of beach marks, post fracture mechanical damage on the fracture surface and shell bearing contact surface and a secondary crack in the oilway groove perpendicular to the fatigue fracture (Figures 16 to 20). The B5 connecting rod small end comprised of a sectioned and damaged small end with distinct identification marks and cut sections boxed separately (Figures 21 to 27). The intact connecting rod small end showed distinct identification marks and gouge like marks on the shell bearing contact surface with no damage (Figures 28 to 35). A section showing the gouge marks was extracted for further examination using a conventional vertical band saw (Figure 36).

3. DYE PENETRANT INSPECTION

Dye penetrant inspection was completed in the oilway groove of the connecting rod small ends along with the gouge marks on the intact connecting rod small end. The DPI showed no bleeding of the dye and absence of crack like features.

4. SCANNING ELECTRON MICROSCOPE EXAMINATION

4.1 APPROACH

The opened crack in the oilway groove and a section of the fracture surface from A5 connecting rod small end was examined in detail using a Scanning Electron Microscope (SEM). The observations are as follows.

4.2 A5 FRACTURE SURFACE

The fracture surface exhibited clear beach marks with an initiation at the shell bearing surface adjacent to the groove, post-fracture mechanical damage and fractography was consistent with fatigue fracture (Figures 37 to 43).

4.3 A5 OPENED CRACK FRACTURE SURFACE

A section from the oilway groove was chilled in liquid N_2 and the crack opened for further examination (Figure 44). The laboratory induced fracture showed a brittle morphology (Figures 45 and 46). The crack fracture surface fractography showed a predominately ductile fracture with brittle fracture and mechanical damage (Figures 47 and 48).

5. METALLOGRAPHIC EXAMINATION

5.1 APPROACH

Transverse sections through the fracture of the opened crack of A5, transverse section through the fractures surface of A5, transverse section through the oilway groove of B5 and a transverse section through the gouge marks of the intact connecting rod small end was mounted in Bakelite and polished by standard metallographic preparation techniques to a 1μm diamond finish. The prepared sections were then examined in the un-etched and Nital etched conditions, using high power light microscopy. The observations are noted in the following paragraphs.

5.2 A5

The opened crack showed a mechanically damaged fracture surface with a brittle laboratory induced fracture (Figures 49 to 52). The fatigue fracture initiated from the shell bearing contact surface and propagated through the small end (Figures 53 to 55). The section showed a quenched and tempered type steel microstructure (Figure 56).

5.3 B5

The section showed an absence of cracks or undesirable features at the oilway groove (Figures 57 and 58). The section showed a quenched and tempered type steel microstructure (Figure 59).

5.4 INTACT CONNECTING ROD SMALL END

The section showed an absence of cracks or undesirable features at the gouge marks (Figures 60 to 63). The section showed a quenched and tempered type steel microstructure (Figure 64).

6. CHEMICAL ANALYSIS

A sample from the connecting rod small ends was analysed by OES technique. The analysis showed the small ends A5 and intact to be consistent with a 42CrMo4 type steel, but B5 to be a 34CrNiMo6 type steel (BS EN ISO 10083-1:2006).

7. HARDNESS TESTING

The prepared transverse connecting rod small end sections were Vickers hardness tested (HV30) after documenting of microstructural features and the results are reported in Appendix 2.

8. CONCLUSIONS, DISCUSSION AND OPINION

The engine had failed in a catastrophic manner as a result of the A5 connecting rod small end failing due to fatigue. The fracture had initiated at the shell bearing contact surface and propagated through the body. The dye penetrant inspection did not reveal any cracking in the oilway groove of all three and in the gouge marks of the intact small end.

The SEM examination identified clear fatigue beach marks with an initiation at the shell bearing surface in a region of the groove. Due to post fracture mechanical damage it was difficult to identify the point of initiation. The microstructure of the three connecting rod small ends did not identify any anomalies. The metallographic section through A5 showed a typical quenched and tempered microstructure with no sub surface inclusions that could lead to sub-surface rolling contact fatigue fractures. The chemical analysis showed B5

to have a higher Cr content than the remaining two. The hardness test results showed the material to be in a quenched and tempered condition with B5 showing a higher hardness a consequence of a higher Cr content despite having a lower C content than the intact and A5. Although the intact small end showed no evidence of consequential features due to the gouge marks, such practices should be avoided at all costs as they can conclude to points of stress raisers.

Fatigue is a progressive failure mechanism arising from cyclic loading and taking time to develop. It usually initiates /propagates from geometrical features such as corners/radii or weld toes if present. No initiation sites were identified in this work due to the consequential mechanical damage. Fatigue is usually followed by another failure mechanism (brittle or ductile fracture), which indicates that the crack in the oil way groove in A5 occurred as a result of the initial fatigue failure. If a component has been designed for fatigue, this type of failure is usually indicative of an excursion from the design conditions or an unexpected event or modification.

Based on the examination undertaken, we conclude that the engine failure can be attributed to various factors in service but the points mentioned above may assist to determine the root cause. It would, therefore in the absence of contrary evidence, appear most likely that the attributing factor for the engine failure had resulted from operation outside the design conditions, rather than any manufacturing defects or material deficiencies.

Report prepared by

[redacted]
Metallurgist

Report reviewed by

[redacted] *CEng FIMMM FWeldI*
Principal Project Metallurgist

Annex D

Lloyd’s Register Examination of Surveyable Machinery Items by Chief Engineers

The Examination of Surveyable Machinery Items by Chief Engineers

Version 1.02
Effective 01 March 2015

Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as the 'Lloyd's Register Group'. Lloyd's Register Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

Clients that arrange for items of machinery to be credited for survey based on examinations by Chief Engineers shall indemnify and hold Lloyd's Register Group harmless against any claim, loss, or liability including any legal costs or other expenses relating to any negligence or omission of the Chief Engineer.

Any dispute, claim, or litigation between Lloyd's Register Group and the Client arising from or in connection with this application shall be subject to the exclusive jurisdiction of the English courts and will be governed by English Law.

1. Introduction

1.1 This document describes how items of machinery may be credited for survey based on examinations by the ship's Chief Engineer

1.2 The arrangement is only applicable to ships operating on a continuous survey machinery (**CSM**) cycle and the procedures to be applied depend on whether or not the ship is operating an approved planned maintenance scheme for machinery.

1.3 The arrangements described in this document do not apply to the ship Operator's superintendents.

2. Ships operating an approved Machinery Planned Maintenance Scheme (MPMS)

2.1 Chief Engineers on ships assigned the ShipRight descriptive note **MPMS** may carry out examinations of selected machinery items to an approved schedule over a five year period corresponding to the existing classification cycles.

2.2 An annual audit of the machinery planned maintenance scheme is required, at which the Surveyor will review the records of examination by the Chief Engineer and undertake confirmatory surveys on those items to be credited that have been examined by the Chief Engineer since the previous Audit.

2.3 The requirements of the relevant ShipRight Procedures and the conditions listed on the *Certificate of Operation of an approved Machinery Planned Maintenance Scheme* are applicable.

3. Ships <u>not</u> operating an approved Machinery Planned Maintenance Scheme

3.1 Under this arrangement, selected items of machinery may be examined by the Chief Engineer while the ship is at sea or in a port where the Lloyd's Register Group is not represented.

It is to be understood that the Operator will carry out as much of the machinery surveys as practicable at ports where the Lloyd's Register Group is represented.

After examination by the Chief Engineer it is the responsibility of the ship Operator to arrange for the attendance of a Surveyor to credit such items. This is to be at the first port where Lloyd's Register's Group's exclusive Surveyors are available.

3.2 A list of applicable machinery items is given in section 4 of this document

3.3 The Chief Engineer is to prepare two signed copies of a statement giving their name and licence details, the item(s) examined, the condition as found and any repairs effected. A template for this statement is attached as an Appendix to this document and is also available to download from ClassDirect Live. One copy of the statement is to be retained on the ship and the other is to be given to the Surveyor.

3.4 A confirmatory survey will be carried out by the Surveyor, at which a review of the records of examination by the Chief Engineer and a general examination of those items to be credited will be carried out.
Following the Chief Engineer's survey of auxiliary engines, the confirmatory survey carried out by the Surveyors is to include the following:

(a). The engine is to be examined running under load and the governor and circuit breaker tested.

(b). All safety devices, remote controls, and automatic alarms to be tested.

3.5 Parts that have been replaced by spares are to be retained and shown to the Surveyor.

3.6 With regard to stand-by units, for example auxiliary engines and main lubricating oil pumps, it will be the responsibility of the Chief Engineer, in consultation with the Master in their joint capacity as representatives of the Operator, to ensure that such items are only opened up for examination under favourable conditions so that no hazard, including fire, to the ship or cargo would result from breakdown of a working unit.

The number of auxiliary generator sets must be such that all services essential to the propulsion and safety of the ship, together with preservation of the cargo, can be supplied when any two of the sets are not working. One of these two sets could then be overhauled while the other remains available as the stand-by set.

3.7 Items such as auxiliary engines, independently driven pumps and compressors are to be examined under working conditions by the Surveyor who, if not satisfied, may require any item to be opened out for inspection.

3.8 The Operator is to instruct Chief Engineers that the survey of auxiliary engines is to proceed as indicated below:

(a). The engine is to be completely opened up and a careful examination made of all cylinders, liners, covers, valves, valve gear, pistons, piston rings, top and bottom end bearings, gudgeon pins, crankcase door fastenings and explosion relief devices.

(b). The top halves of all main bearings are to be removed and at least two bottom halves turned out for inspection. If these are found in good condition the remaining bottom halves need not be removed

(c). A very careful examination is to be made of all crankpins and journals for cracks especially at the fillets and in the vicinity of oil holes.

(d). The crankweb deflections are to be measured and recorded. Care must be taken to ensure that the journals are resting on the main bearings when the readings are taken.

(e). The cylinder liners are to be gauged and the wear recorded.

(f). The lubricating oil cooler is to be opened, examined and tested.

(g). Any direct driven lubricating oil pumps, cooling pumps, air compressors, etc., are to be opened up and examined.

(h). It is to be verified that all safety devices are in efficient working condition.

3.9 Any damage, defect or breakdown which could invalidate the conditions for which class has been assigned, are to be reported to a Lloyd's Register Group office without delay.

3.10 Any machinery item which is subject to a condition of class is excluded from this arrangement and is to be dealt with by the Surveyor.

4. Applicable Machinery Items

4.1 Items of machinery which may be examined by the Chief Engineer are given below:

(a). **Main Propulsion Diesel Engines**:

- Cylinder covers.
- Valves and valve gears.
- Cylinder liners.
- Pistons and piston rods.
- Connecting rods, crossheads, top end bearings, guides, gudgeon pins and bushes.
- Fuel injection pumps and fuel booster pumps.
- Scavenge blowers and air coolers.
- Turbocharger.
- Detuners, dampers and balancer units.

- Camshaft and camshaft drive.
- Main engine thrust bearing.
- Governor.

(b). **Auxiliary Diesel Engines**:
- Complete unit including coolers and pumps (See section 3 above).

(c). **Auxiliary Steam Turbines**:
- Complete unit including coolers and pumps (See section 3 above).

(d). **Auxiliary Machinery**:
- Main engine driven pumps e.g. bilge, lubricating oil and cooling water.
- Independently driven pumps (and associated motors and cables where insulation resistance readings are supplied), e.g. bilge, ballast, fresh water cooling, sea-water cooling, lubricating oil and oil fuel transfer.
- Main engine fresh water and lubricating oil coolers.
- Low pressure heaters used in high viscosity fuel systems of internal combustion engines.
- Condensers
- Feed heaters /drain coolers
- Air compressors and their safety devices.
- Forced or induced draught fans.

(e). **Steering Machinery**:
- Steering gear pumps.

(f). **Shafting**:
- Intermediate shafts.

(g). **Pressure Plant**:
- Adjustment of exhaust gas boiler safety valves under steam.

(h). **Deck Machinery**:
- Windlass and windlass machinery.

(i). **Refrigerated Cargo Installations**:
- Reciprocating refrigerant compressors.
- Brine pumps.
- Condenser cooling pumps.
- Liquid refrigerant circulating pumps.

(j). **Ships for Liquefied Gases**:
- Reciprocating refrigerant compressors.
- Reciprocating cargo gas compressors.
- Condenser cooling pumps.
- Circulating pumps (where fitted).

(k). **Ships fitted with Approved Inert Gas Systems**:
- Scrubber units.
- Independent gas generators.

5. Inapplicable machinery items

5.1 Items of machinery which are <u>not</u> to be examined by the Chief Engineer are given below:

(a). **Main Propulsion Diesel Engines:**
- Crankcase doors and relief devices.
- Crankpins, bearings and webs.
- Engine trial.
- First start arrangements.

- Main journals and bearings.
- Scavenge relief devices.

(b). **Main steam turbines:**
- Complete unit.

(c). **Gas turbines:**
- Complete unit.

(d). **Reduction gearing:**
- Reduction/increase gearing, flexible couplings and clutches.

(e). **Shafting:**
- Tailshafts.
- Sternbushes.

(f). **Propellers:**
- Complete unit.

(g). **Auxiliary machinery:**
- Pumping arrangements.
- Sea connections.

(h). **Pressure plant:**
- Boilers and other pressure vessels.
- Boiler fuel oil heaters.
- Steam pipes.
- Manoeuvering valves and bulkhead stop valves.
- Starting air pipes.

(i). **Electrical equipment:**
- Electrical equipment other than auxiliary motors.

(j). **Control equipment:**
- Main engine controls and controls associated with Class Notations, e.g. UMS, CCS, ICC, IP and DP.

(k). **Steering machinery:**
- Surveyable items other than the steering gear pump.

(l). **Ships fitted with Approved Inert Gas Systems:**
- Remaining components not listed in 4.1.(k).

(m). **General Items:**
- Holding down bolts and chocks.
- Machinery damage, repairs and alterations.

6 Appendix

The appendix contains the template to be used by Chief Engineers to record the results of their examination of machinery items on ships not operating an approved Machinery Planned Maintenance Scheme

Chief Engineer's Statement of Examination of Surveyable Machinery Items

This form is to be used to record the results of the examination of machinery by the ship's Chief Engineer on ships which are not operating an approved Machinery Planned Maintenance Scheme.

Two signed copies of this statement are to be prepared. One copy of the statement is to be retained on the ship and the other is to be presented to the Surveyor. A confirmatory survey will be carried out by the Surveyor, at which a review of the records of examination by the Chief Engineer and a general examination of those items to be credited will be carried out.

Refer to the Lloyd's Register Group document The Examination of Surveyable Machinery Items by Chief Engineers for further instructions on this arrangement and for a list of applicable machinery items.

General Details	
Ship Name:	IMO No:
Name of Ship Operator:	Total number of Items seen:

Chief Engineer details	
Name of Chief Engineer :	
Chief Engineer's License Number:	Chief Engineer's License Date of Expiry:
Name of Administration issuing License:	

Signature	Notes
Date:	1 This statement is to be presented to the Surveyors at the time of confirmatory surveys.
Signature of Chief Engineer (named above):	2 The results of examination of machinery items by Chief Engineers are to be recorded on the following page.
	3 After examination by the Chief Engineer, it is the responsibility of the ship Operator to arrange for the attendance of a Surveyor to credit such items. This is to be at the first port where the Lloyd's Register's exclusive Surveyors are available.

Chief Engineer's Statement of Examination of Surveyable Machinery Items

Results of Examination			
1. Enter the date of examination, the Lloyd's Register Group machinery Master List Number and corresponding description as shown of the Lloyd's Register Group Master List of Surveyable Items.			
2. Enter details for each Master List item examined in a separate section. Use additional copies of this page, as necessary, to record the results of the examination of multiple items of machinery. Attach each page to the front page signed by the Chief Engineer.			
Details of Items Examined			
Date of Examination			
Masterlist Number		Description	
Condition, as found			
Repair, if any			
Details of Items Examined			
Date of Examination			
Masterlist Number		Description	
Condition, as found			
Repair, if any			
Details of Items Examined			
Date of Examination			
Masterlist Number		Description	
Condition, as found			
Repair, if any			