



Evaluation of Controllable Pitch Propeller (CPP) Blade – Maunalei

SOCOTEC Project LF221713

LF221713-P-01

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November 8, 2022

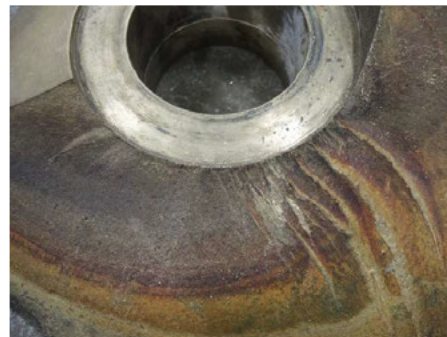
VISUAL EXAMINATION

- Visual examination in the as-received condition at Brady Marine Repair confirmed the presence of two cracks at hub bolt hole counterbore edges.
- No evidence of significant corrosion attack, wear, or impact damage to the blade was observed.
- **Manufacturer stamped markings:**
 - F_120320_01 DNV_GL N141ZA4D 29-05-20 BLD N-2433 APH1241 P4 G_4768 KG
8934.7 KG/M SKEW=40 RH MAN ENERGY SOLUTIONS
- **Hub region was subsequently sectioned by Brady Marine for transfer to SOCOTEC.**



CRACK EXTRACTION

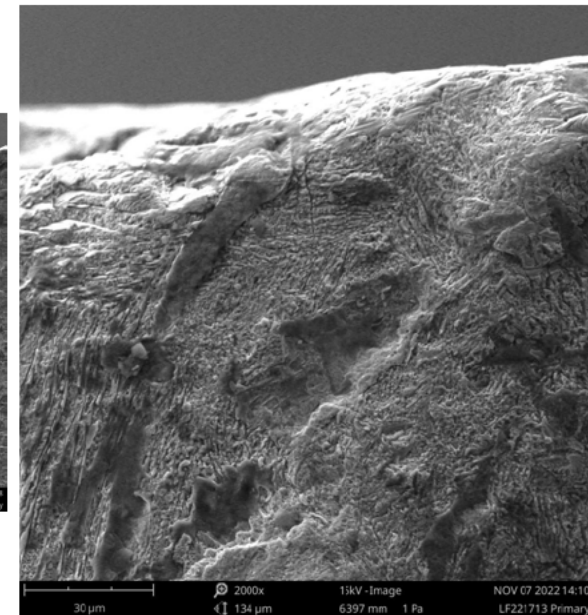
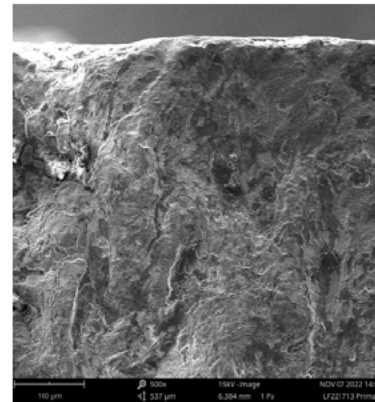
- All blade sections cut by Brady Marine were transferred to SOCOTEC, including the hub region containing the two cracks.
- Bandsaw sectioning was conducted to extract the areas of the hub that contained the cracks.
- The conchoidal (i.e., thumbnail-shaped) appearance of the crack fracture surfaces and the ratchet marks observed at the bolt hole counterbore edges were visually consistent with progressive cracking in the nature of high-cycle fatigue that initiated at the bolt hole counterbore edges.



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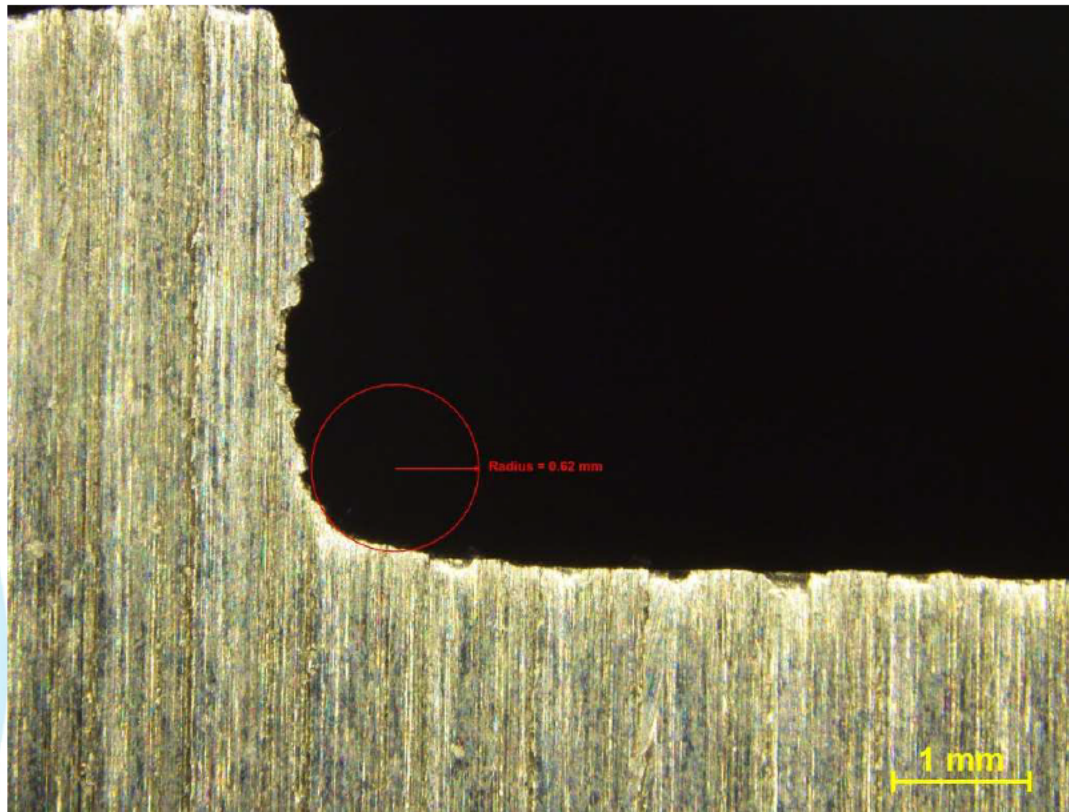
FRACTOGRAPHIC EXAMINATION

- **Optical stereomicroscopic examination of crack initiation locations at the bolt hole counterbore edges confirmed the presence of ratchet marks. No evidence of casting discontinuities that, if present, could have contributed to the fractures was observed.**
- **Isolated areas of shrinkage porosity were observed away from the fracture initiation regions.**
- **Scanning electron microscopic (SEM) examination of representative fracture surface areas confirmed a furrowed morphology with striations, features consistent with progressive cracking in the nature of high-cycle fatigue.**



BOLT HOLE COUNTERBORE RADIUS

- Optical stereomicroscopic examination of the bolt hole counterbore cross-section measured a radius of less than 1 mm.



COMPOSITIONAL ANALYSIS

- Quantitative compositional analysis of a specimen sectioned from the hub region was conducted utilizing atomic optical emission spectroscopy (OES) and inductively coupled plasma mass spectrometry (ICP-MS).
- The test results were in conformance with MAN Material Specification MA5X except for silicon content that exceeded the specified maximum.

CHEMICAL ANALYSIS RESULTS (WT. %)

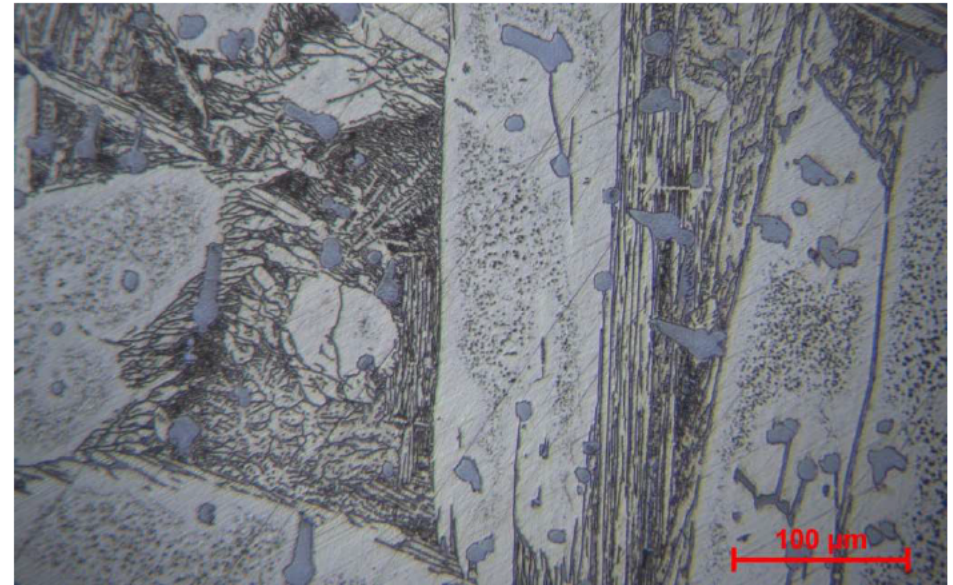
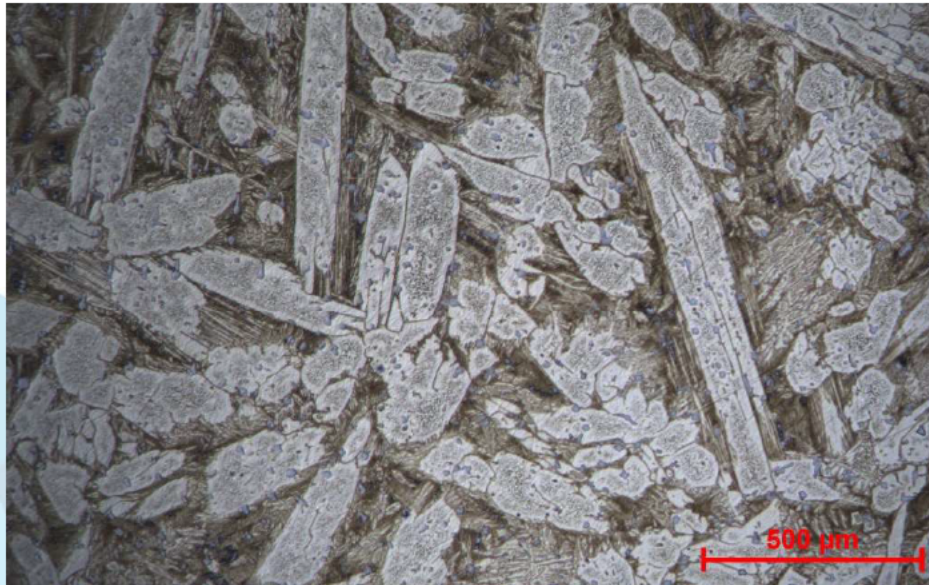
Element	Per MAN MA5X	Specimen
Cu	76.0, min.	78.3
Al	8.5 – 11.0	9.8
Fe	3.5 – 5.5	4.3
Mg	0.05, max.	<0.01
Mn	3.0, max.	1.1
Ni	4.0 – 6.5	4.7
Pb	0.05, max.	0.01
Si	0.10, max.	0.17
Sn	0.20, max.	0.03
Zn	0.50, max.	0.30

MECHANICAL TESTING

- **Charpy V-notch (CVN) impact testing of specimens sectioned and machined from the hub region was conducted in accordance with ASTM E23 at 10°C (50°F).**
- **Testing of four specimens averaged 7 ft-lb (9.5 Joules), below the minimum requirement of 21 Joules for Baltic ice class from MAN MA5X specification.**
- **Tensile testing of a specimen sectioned and machined from the hub region is scheduled to be completed 11/8.**

METALLOGRAPHIC EVALUATION

- Metallographic evaluation of a specimen sectioned and prepared from the hub region exhibited a microstructure of α -phase particles in a β -phase matrix, consistent with a cast copper alloy.




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