

STEAM TURBINE FAILURE

Fatigue induced blade ruptures



BACKGROUND

Two low pressure (LP) steam turbine rotor blade ruptures were discovered during an inspection that was carried out due to high vibrations during start-ups. The two ruptured blades had both been mounted in row 19, the 1st row in the LP stage. The blade material was specified to conform with EN 1.4923.

FINDINGS AND CONCLUSIONS

- Chemical composition and hardness measurements showed that the rotor blade material conformed with the specifications (Table 1-Table 2).
- The macroscopic appearance with beach marks visible on the fracture surfaces (Figure 2) indicated that the blade fractures had been caused by fatigue, initiated at the suction side of the blade roots. Beach marks are macroscopic concentric rings that represent sudden changes in load and/or environmental conditions.
- The total number of beach marks was estimated to be 30-50 which may be interpreted to equal the number of starts/stops needed to cause the fracture. The different colours of the beach marks indicate various degrees of oxidation which can be referred to different stages under which the fatigue crack has propagated.
- A detailed study of the fracture surface in SEM showed the presence of so-called striations (Figure 3). Striations are microscopic parallel lines associated with fatigue failures where each line represents the crack front during one load cycle. The shape of the striations further confirmed that the fractures had been initiated at the suction side of the blade roots.

INVESTIGATION

- On-site inspection and visual examination
- Fractography of the ruptured blades (SEM)
- Verification of chemical composition (XRF)
- Hardness measurements (Brinell)
- Microstructural studies (LOM)

SEM - Scanning electron microscopy
 XRF - X-ray fluorescence
 LOM - Light optical microscopy

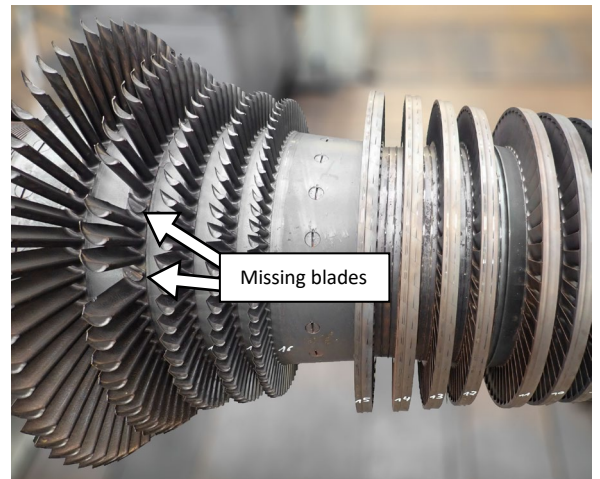


Figure 1. Two missing blades in LP-stage of steam turbine.

Table 1. Chemical composition of blade root [wt.-%]

Sample	Si	V	Cr	Mn	Fe	Ni	Mo
Blade root	0.5	0.3	11.8	0.8	85	0.6	1
Specified material (EN 1.4923)	0.1–0.5	0.25-0.35	11.0–12.5	0.4–0.9	Bal	0.3–0.8	0.8–1.2

Table 2. Measured hardness with corresponding tensile strength.

Sample	Hardness [HB]	Tensile Strength [MPa]
Blade root	260	880
Specified material (EN 1.4923)		800–950

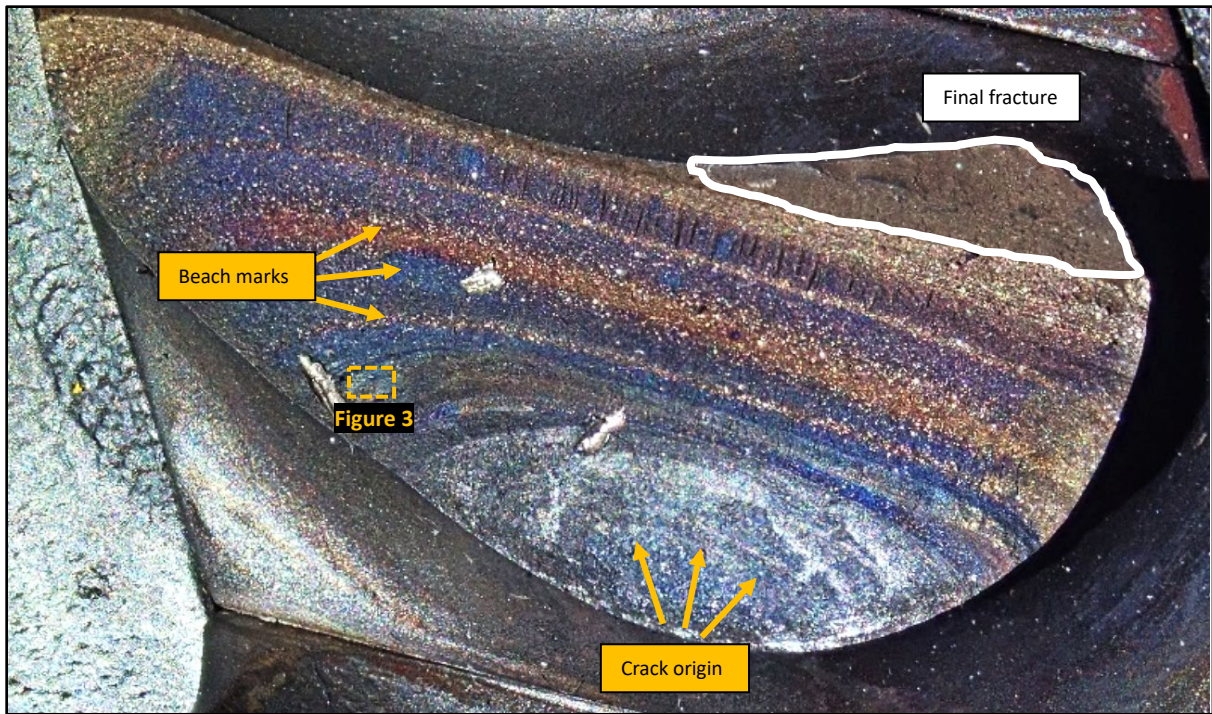


Figure 2. Fracture surface of the blade root, shows a large number of beach marks indicating that the fracture has been caused by fatigue.

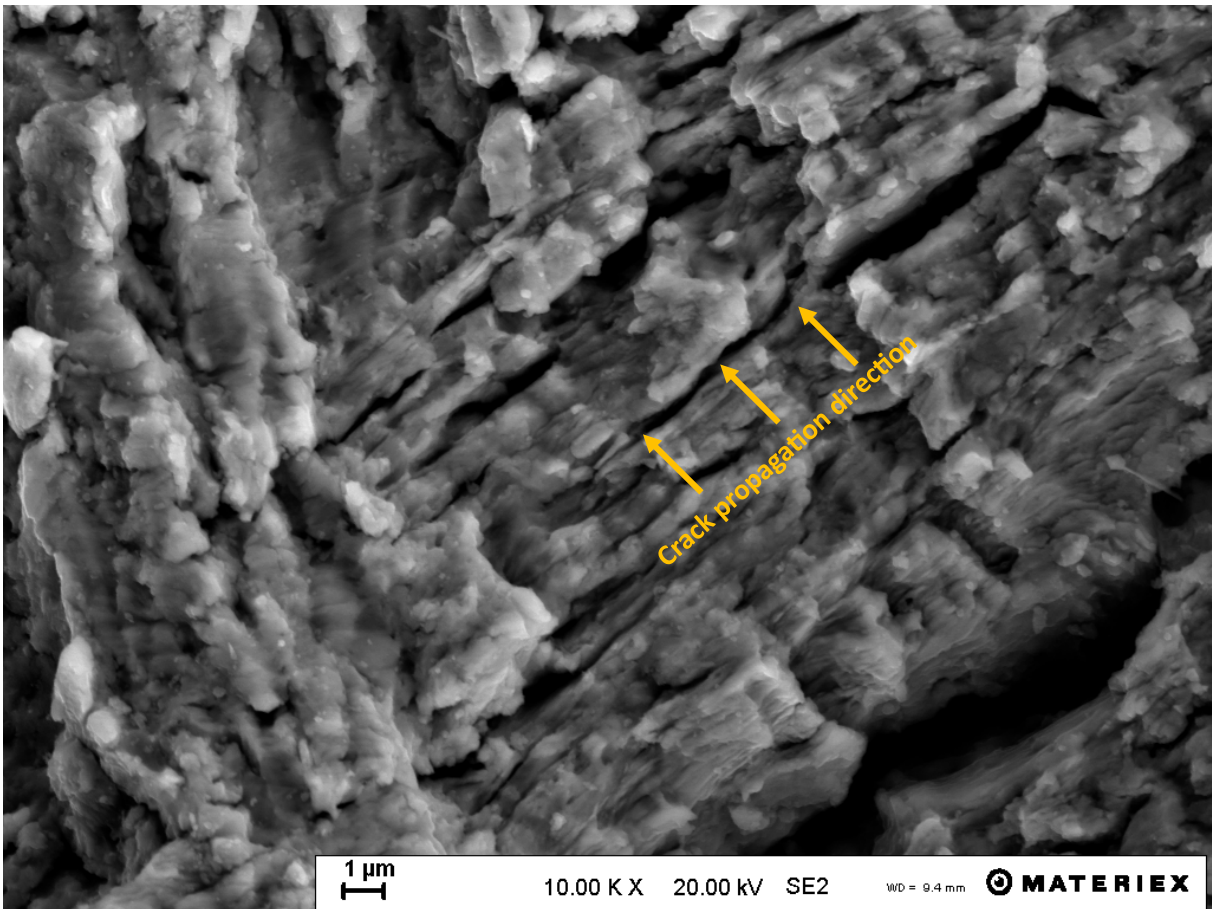


Figure 3. SEM-image showing fatigue striations visible at high magnification. Arrows indicate crack propagation direction.