Engineering Failure Analysis 56 (2015) 545–554

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Steam turbine rotor discs failure evaluation and repair process implementation

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A R T I C L E I N F O

Article history:
Received 23 June 2014
Received in revised form 14 October 2014
Accepted 15 October 2014
Available online 4 December 2014

Keywords:
Damage
Stress corrosion
Steam turbine
Rotor disc

A B S T R A C T

Two rotor discs failed in a 84-MW unit installed in a power plant. The failure was evidenced by large circumferential fractures of blades attachments in both discs. Disc failure was evaluated by investigating rotor operation history, steady state stress analysis by finite element (FEA), disc fracture surface fractography and deposit evaluation. It was found that this disc failure was driven by stress corrosion due to significant static stresses, humid ambient operation and disc material susceptibility. To correct disc failure and restore turbine original characteristics, a disc welding repair procedure was developed. This repair process was implemented and rotor discs restored by weld deposition, post weld heat treatment and machining. As a result, the rotor was returned to service and its useful life extended.

1. Introduction

Many steam turbines in power generation are operating beyond their design life reaching 30–40 years of commercial service. Turbine rotating components including rotors, discs and blades are among the most critical elements due to high thermal and mechanical stresses which can affect their integrity and useful life. Service-induced damage to these components can lead to severe economic penalties for power generation utility and in some cases to catastrophic failures. In the case of low pressure rotors, the most popular material is forged 3.5NiCrMoV material according to ASTM A 470 classes 5–7.

There are many mechanisms that can cause damage to low pressure (LP) steam turbine components. These mechanisms are thermo-mechanical fatigue, stress corrosion cracking, creep, erosion, corrosion and foreign object damage (FOD). Fatigue can be characterized as low-cycle fatigue, high-cycle fatigue, thermal fatigue or corrosion fatigue. Stress corrosion cracking (SCC) refers to damage that occurs in stressed components when exposed to corrosive environments [1–6]. According to [5], any rotor with more than 20 years of service should be inspected for SCC. Water droplets condensed from saturated steam can damage rotors in seal areas due to erosion. Corrosion can lead to the gradual deterioration of rotor surfaces due to pitting which act as stress risers in high stress regions.

Rotor repair through welding is one of the principal means for extending rotor life. Repair processes are classified into different classes including weld build-up of gland seals and bearing journals, weld restoration of individual rotor steeples, weld build–up of rotor wheel rims, repair of circumferential cracking, replacement of rotor and welding sections in new blade ring forgings.

This paper describes a case history of the failure evaluation and repair process of stress-corrosion damaged 84-MW steam turbine rotor by means of weld built up.

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http://dx.doi.org/10.1016/j.engfailanal.2014.10.010
1350-6307/

2. Methodology

The rotor under evaluation corresponds to an 84-MW, 3600 rpm steam turbine. This unit has a flow high/intermediate/low-pressure turbine composed of 13 stages of blades. This turbine had accumulated 332,000 operation hours (40 years) to failure. A turbine rotor general view is shown in Fig. 1. The failures occurred in stages L-3 and L-4 which are grouped in 6 and 5 blades, as indicated by arrows. Fig. 2 shows axial cracks in the L-3 and L-4 stage disc blade grooves, and Fig. 3 shows circumferential cracks in these same grooves. The circumferential cracks extend to approximately 350 mm in both stages.

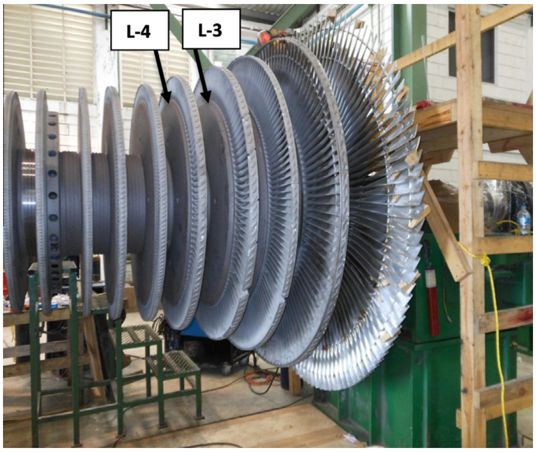

Fig. 1. General view of the rotor of the 84 MW steam turbine; the arrows indicate failed discs.

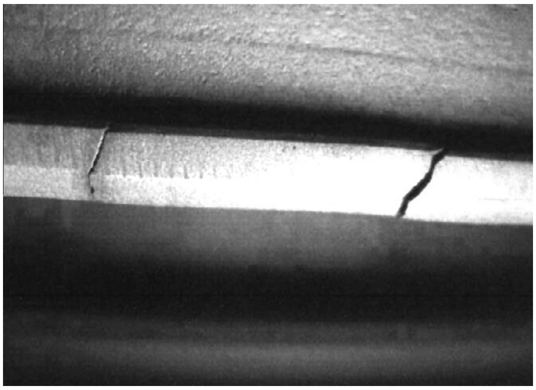

Fig. 2. Axial cracks in the blade grooves.

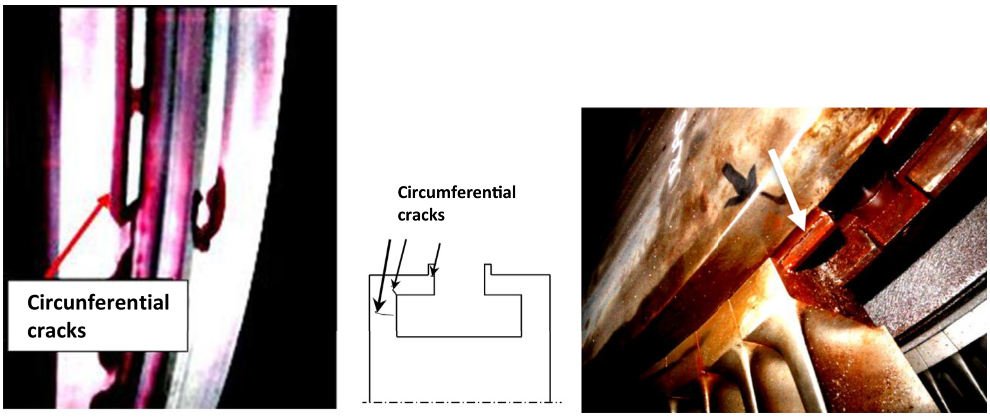

Fig. 3. Circumferential cracks in the blade grooves.