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Failure analysis of a steam turbine rotor

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ABSTRACT

A large and growing portion of electricity is being produced by aging thermal power plants, and although steam turbines are being constructed with excellent high quality materials such as CrMoNiV steel, varying forms of metallurgical degradation due to creep and/or fatigue could still affect the parts and components during long-term operation at high temperatures [1]. Moreover, the de-regulated electricity market, which has existed for approximately 15 years, has led to energy companies operating their power plants in a flexible manner, as opposed to continuous operation, in order to maintain profitability in a very competitive commercial environment [2].

This paper investigates the rotor turbine failure of a 60 MW unit of a thermal power plant. The rotor was made of CrMoNiV steel, and the failure occurred after approximately 10 years in operation. Several different analyses were carried out in order to identify the failure's root cause: visual examination, SEM fractography, micro-hardness measurement, and microstructural characterization.

The fracture of the shaft was located at the first stage [2] and the fatigue fracture extended over roughly 75% of the initial cross section. Primary failure causes were identified by the analyses performed, and the observed fracture mechanism was traced back to high cycle fatigue damage. The origin of the fatigue phenomenon can be traced to the stress field generated on the rotor surface by both the frequent startup cycles and the blade fixing method.

1. Introduction

Steam turbine rotors are among the most critical and highly stressed components in modern power plants [3]. The consequences of a rotor failure are severe in terms of both safety and economic impact. For this reason electric power utilities and manufacturers quantify and limit the risk of such failures using the concept of "rotor life", which is the maximum number of service hours and hot and cold starts to which a rotor can be subjected [3].

However, de-regulation of the electricity market has led energy companies away from continuous operation to a more flexible operating schedule in order to maintain profitability in a competitive commercial environment. The principal consequence of de-regulation is an increase in annual startup cycles, which enhances the degradation rate of rotor material.

These rotors are often made of CrMoNiV steel and have a limited lifespan due to creep and thermal fatigue.

Rotor surface thermal stresses are greatest in areas of high mechanical stress concentration and where a high bore to periphery temperature differential exists. The most burdensome combination of these conditions is found at notches such as the heat relieve grooves of the glands at the inlet end of the rotor, fillet radii at the base of disks, balance holes in the disks and blade grooving, in reaction-type rotors.

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