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Turbine blade failure in a thermal power plant

Goutam Das*, Sandip Ghosh Chowdhury, Ashok Kumar Ray, Swapan Kumar Das, Deepak Kumar Bhattacharya

Materials Characterisation Division, National Metallurgical Laboratory (CSIR), Jamshedpur-831007, India

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Abstract

The failure of a LP (low pressure) turbine blade of a 220 MW thermal power plant is presented. The blade was made of martensitic stainless steel and the structure was tempered martensite. There was no evidence of degradation of blade material. The fracture took place at the aerofoil region, 113-mm from the root. Throughout the blade surface Si rich phases were detected. Several pits/grooves were found on the edges of the blades and chloride was detected in these pits. These were responsible for the crevice type corrosion. The probable carriers of Cl^{-} were Ca and K, which were found on the blade. The failure mode was intergranular type. Possibly the ultimate failure was due to corrosion-fatigue.

Keywords: Turbine blade; Corrosion fatigue; Failure analysis; Fractography; Intergranular fracture

1. Introduction

In recent times, LP blades of a steam turbine are generally found to be more susceptible to failure than IP (intermediate pressure) and HP (high pressure) blades. Among the various blade materials the most popular is 12% chromium martensitic steel. It has an excellent combination of strength, toughness and corrosion resistance as well as high inherent damping characteristics [1–3].

The present paper reports the investigation of the failure of a blade in the LP stage of a thermal power plant of 220 MW capacity. The unit was shut down because of noise in the turbine assembly. After opening the turbine casing, one blade in the LP region was found fractured. The blade before fracture had completed 33,000 h of service. The blade which had failed was from the 29th stage. This stage has 120 blades. Thus, there are 15 such buckets. Bucket 8 contained the fractured blade (blade no 61). The fracture took place at the aerofoil region, 113-mm from the root. The fractured blade was number 4 in that bucket. The other blade, which did not fail but completed the same number of cycles, was the 5th from the same bucket. The lacing rods connecting the other blades i.e. 3rd to 6th were also found to be broken, however, the remaining portion of the lacing rods on both ends remained intact. These failures were presumably a result of impact by the broken piece of the blade mentioned earlier. The objective of the investigation was

* Corresponding author. Tel.: +91-657-271-710; fax: +91-657-270-527.
E-mail address: asokroy@nmlindia.org (G. Das).

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to identify the root cause of failure and to ascertain whether it was due to a materials related problem or due to changes in operational parameters arising from the grid frequency, boiler water chemistry etc. Investigation was also conducted on a blade nearby the fractured blade and also on a blade which had completed 100,000 h of operating period.

2. Experimental procedure

Chemical analysis of the blade material was carried out by a standard wet method. A portion of the failed blade with the fracture surface was cut for fractography study. A portion of the fractured blade (100 mm away from the fracture surface, as shown in Fig. 1) was cut for metallography. A few random pieces were also cut from the other two blades as already mentioned (i.e. 33,000 h service exposed and 100,000 h service exposed) for SEM and metallography. The metallography samples were prepared by using standard metallographic techniques and etched with Glycergia (a dilute solution of HCl, HNO_3 and glycerol). The microstructure of the blade material was analysed by optical microscope and a JEOL-840 scanning electron microscope (SEM) equipped with an energy dispersive X-ray (EDX) analysis facility. Hardness values were measured using a Vickers Hardness Testing machine under 10-kg load.

3. Results

3.1. Visual inspection

The fractured surface of the blade, which failed in the first place, revealed a smooth surface. Beach marks were observed and indicated that the crack might have originated from the thinner side of the blade. Some portion of the fractured surface appeared black which is indicative of the presence of Fe_3O_4 (magnetic) scale. The blade revealed the presence of adherent scale of varying thickness.

3.2. Chemical analysis

The blade material was found to have the following material composition: C-0.21; Si-0.51; Mn-0.43; Cr-13.64; Mo-0.22; Ni = 0.51; balance-Fe. This material conforms to ASTM 410 grade martensitic stainless steel.

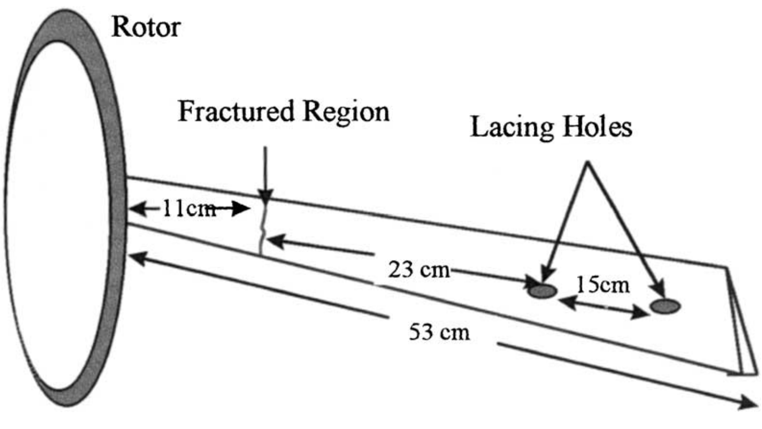

Fig. 1. Schematic of the turbine blade with the fractured region as shown.