PROCEEDINGS : COFA–1997
©NML JAMSHEDPUR; pp. 17-23

Failure analysis of a steam turbine casing

G. DAS
National Metallurgical Laboratory, Jamshedpur - 831 007.

ABSTRACT

In case of turbine components the fluctuation of operational parameters are less compared to boiler components. Even then, the turbine components often fail due to thermal fatigue, corrosion, erosion, stress corrosion cracking, fretting fatigue and corrosion fatigue. The failure analysis data of a failed component is necessary for safe operation of plant and for the prevention of further failure. In this paper, failure of a lower casing of high pressure turbine stage, has been analysed. The lower casing was weld repaired after detecting cracks which was found after 30 years of service. But after 5 years of operation the repaired casing showed formation of cracks in the weld region. It was shown that the cracks were originated in the weld region due to improper choice of the welding electrodes. It has been suggested that using proper weld electrodes and proper weld process the casing may operate safely for another few years.

INTRODUCTION

Modern power plant is designed to operate for a long period (more than 3,00,000 hours). A huge variety of materials are required for its complex design and these materials are operated under various condition from moderate temperature to 650°C at high pressure (180 bar) under different adverse environment [1]. So, it is very much important to understand the metallurgical process under various condition as well as time dependent metallurgical developments for safety and economy. Designer of plant components will be able to achieve more advanced and economic designs if a clear structure property relationships are available to them.

In recent time there is a growing demand to extend the life of several existing power plants which have crossed their design life. To assess the remaining life of these existing power plants, the failure history and analysis of the respective components along with other data like design parameters, metallurgical behaviour, operational parameters will play a vital role. So, the importantance of failure analysis of failed components are enormous.

For modern fossil fired power plant, the turbine itself is complex assembly of several components made of various materials depending upon their requirement

Limit of a single cylinder turbine is 100 MW. For more than 100 MW, a typic plant may have a high pressure (HP), an intermediate pressure (IP) and one or tw or three low pressure (LP) zone [1,3]. High pressurized steam from steam generatir unit are fed into turbine through nozzle to rotate the turbine blades.

Turbine Casing -- Materials and Failure Mode

A steam turbine casing is essentially a pressure vessel with its weight sup ported at each end on the horizontal centreline. It is massive cast structure made of Cr-Mo-V steel. Materials used for casing and their maximum operation tempera ture are listed in Table 1 [2,3]. One hand it contains steam pressure and at the sam time it maintains support and allingment of the internal components.

Table 1 : Casing materials for steam turbine

	Typical composition						Approx max. ser. temp.	Failure mode
	C	Mn	Cr	Mo	Ni	V	°C	
Carbon steel (cast)	0.25	1	-	-	-	-	450	Thermal fatigue, creep
2.25Cr-1Mo (cast)	0.15	0.5	2.25	1	-	-	580	
0.5Cr-0.5Mo-0.25V (cast)	0.15	0.5	0.5	0.5	-	-	580	
1Cr-0.5Mo-0.25V (cast)	0.15	0.5	1	1	-	-	580	

Cracking (thermal fatigue cracking) and casing distortion (thermal or creep are the principal concern from the point of failure. Cracking of the casing can lea to steam leakage and in extreme situation to bursting. Casing distortion can caus damage by allowing contact between stationary and rotatory parts. Pressure con tainment requires thick, rigid walls whereas thermal gradient considerations re quire thin flexible walls. Thermal distortions still occur due to rapid start stop cycles, water induction and transient events. Distortion may exist at horizontal and vertical joint flanges, seal surfaces, nozzle and stationary diaphragm fits, etc. Creep distortion has been observed in a few high temperature/high pressure casing. High thermal stressed zones are critical for crack initiation. Cracks are also observed at the steam inlet and outlet section [1,2,3].

65% of failure in the HP and IP section are due to low cycle fatigue whereas failure due to brittle fracture are 30% and only 5% failure due to creep [2]. Some of the failure are the combination of the above three. Repeated tensile and compressive thermal stresses result the formation of low-cycle-fatigue cracks, which is transgranular in nature. Catastrophic brittle fracture will occur if the cracks are allowed to grow to critical size. Degradation of toughness of the materials due to long service exposure results the brittle cracking and rapid growth occurs due to each thermal cycle. These cracks can be transgranular or intergranular. The brittle form of low-cycle-fatigue cracking is the most severe form of cracking. Most of the cracks, if found during inspection, are repaired by grinding, welding and metal stitching.

Potential failure mechanism at low temperature (below 200°C) are brittle fracture and fatigue. Whereas, fatigue (low and high cycle), creep fatigue, creep and corrosion of various type are the principal failure mode for high temperature. Failure can be defined as the development of defects and that can grow to a size as to make the specific components inoperable. Components can be failed either by slow growth of defects or it may be catastrophic in nature depending upon the position and nature of the defects and also on the operational parameters [2,4,5].

CASE STUDIES

FAILURE ANALYSIS OF A WELD REPAIRED LOWER TURBINE CASING AFTER 5 YEARS OF SERVICE

Initially the turbine was under operation for several years. After that a defect was found on the lower casing of HP. Then the weld repair was carried out. But again, after 5 years a crack was found on the weld zone and a piece from that weld region with surrounding base material was sent to us for failure analysis [6].

Findings

Microstructure

The cut piece from the lower turbine has been shown in Fig. 1. There was a hole perceptible by the naked eye observed on the top surface of the weldment (Fig. 1) associated with the piece. Microcracks were also found to be nucleated from the hole (Fig. 2). Scanning electron microscopic (SEM) analysis showed the presence of cracks along the grain boundary on the austenitic microstructure of the weld metal (Fig. 3). Microstructure of the weld metal showed fine cellular/dendritic morphology, typical of as solidified structure (Fig. 4). Precipitates (purely

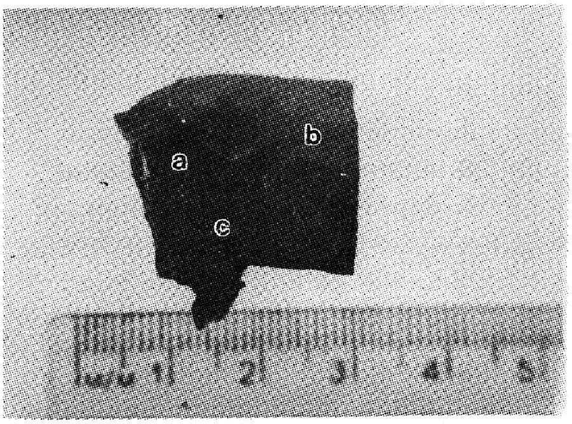

Fig. 1 : Cut portion, showing weld region (a), base metals (b) and preexisting hole (c)

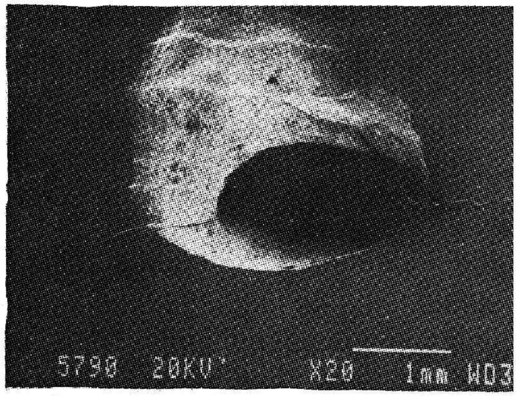

Fig. 2 : Microcracks nucleated from the hole

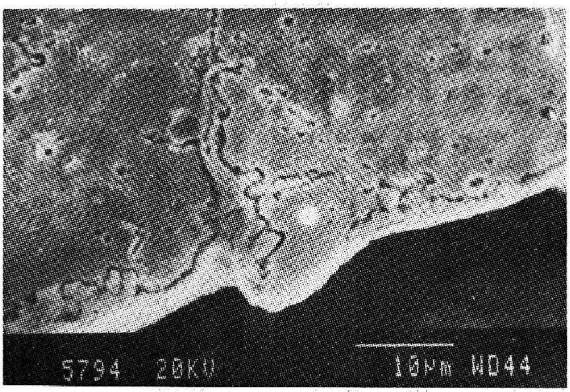

Fig. 3 : Cracks along the grain boundary and precipitetes of Cr & Mo carbides

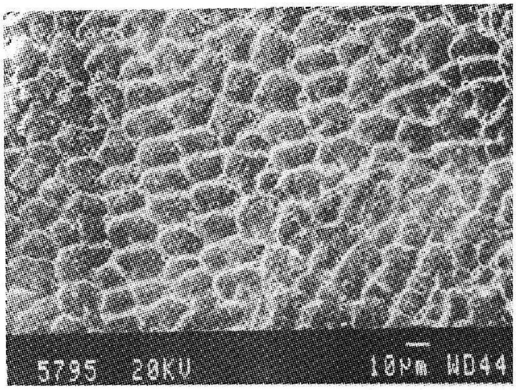

Fig. 4 : SEM micrograph of weld metal, showing cellular morphology

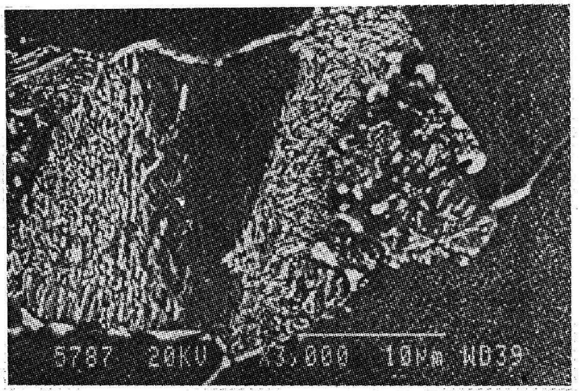

Fig. 5 : SEM micrograph of base metal, shows ferrite grains and precipitates in the pearlitic region

those of Cr carbides) along the grain boundary were identified. Some of the precipitates, also along the grain boundary, indicated the presence of Mo also (Fig. 3).

Base metal showed ferritic grain and carbide precipitation along the grain boundary (Fig. 5). The carbide was found to contain Cr, Mo, Mn and Fe. They remained in the original perlitic regions. The extent of spherodization was not yet complete. Table 3 [7] showed the extent of degradation ('5' being the most degraded and '1'; being the original) of materials under service condition in relation to observed microstructure.

Table 3 : Classification of microstructure

Class	*Microstructure*	*Remarks*	*Degradation*
I.	Initial microstructure	Can be verified by metallography if data available	None
II.	Fine changes in second phase precipitation	Detected only by TEM	In the incubation period, lack of data on high temperature properties
III.	Spheroidization of carbides and grain growth	Information by insitu metallography is possible	-do-
IV.	Isolated cavities	-do-	Still in the incubation period. The lack of data on high temp. properties with this kind of microstructure are still more acute
V.	Alinged cavities	-do-	Case for concern
VI.	Crack initiation	-do-	Requires judgement to decide on continuaion of components

Considering the above classification the present microstructure will be under class III. Although, a few pores and cavities were observed randomly in the grain boundary the damage due to creep was not found to be significant (Fig. 5). Since the specimen belonged to a casting, to much importance was not given on cavities which were possibly present since inception.

Composition

The weld metal was found to be non-magnetic whereas base metal was magnetic in nature. It confirmed, therefore, that the filler material was used of austenitic type whose chemistry was different from that of the base material which is of the 1Cr-1/2Mo ferritic steel type. The weld composition was : 0.32 Si, 24.11 Cr, 4, C ≈ 0.2%, Mn, 32 Ni, 39 Fe whereas the base material composition is ; 0.26 Si, 0.89 Cr, 1.1 Mn, 0.66 Mo, Fe bal.

Fractography

Fractographic observation showed that the crack had propagated only in the weld region originating from the defects in the weld metal such as voids, cavities which had possibly developed during weld repair operation (Fig. 6). Thermal fatigue appears to be main mechanism responsible for the crack growth deteriorating the life of weld zone (Fig. 7). Striations observed could be taken as the signature of the thermal fatigue or thermo-mechanical fatigue which is not uncommon for thick casting used for casing of turbines. Secondary cracks identified in the fractographs indicated intergranular type of fracture resembling the presence of embrittled microstructure (Fig. 8).

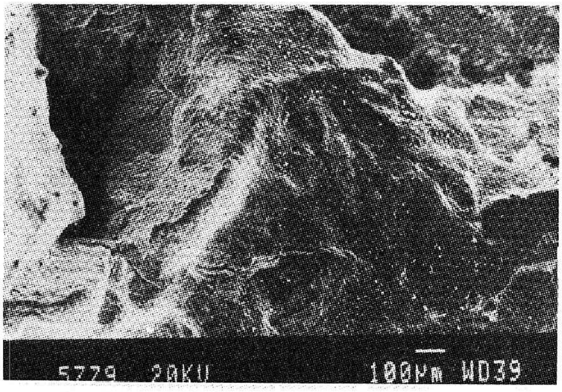

Fig. 6 : Cracks propagated in the weld zone possibly from pre-existing hole

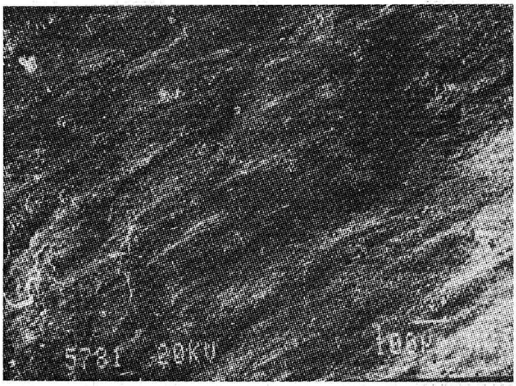

Fig. 7 : Slow growth zone of fatigue fracture

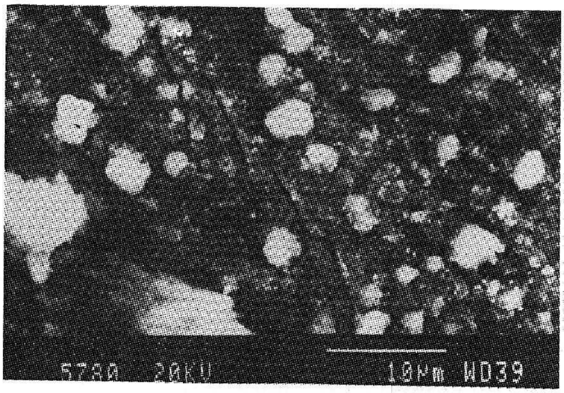

Fig. 8 : Secondary cracks identified in the fractograph.

CONCLUSIONS

Considering the above findings and correlating with the data available in the literature, it is concluded that the crack originated in the weld metal due to improper choice of the welding electrode and perhaps the welding process. The present weld material should be removed completely and the proper weld repair should be done to exploit the remaining life of the base metal which is yet to degrade.

REFERENCES

[1] Modern power station practice, "British Electricity International", Pergamon Pres, Third Edition, 1992.

[2] Damage mechanism and life assesment of high temperature components, R. Viswanathan, "ASM International", Metals Park, Ohio.

[3] Metals Handbook, Failure analysis and prevention, Vo. 10, 8th edi., ASM, 1975.

[4] Analysis of metallurgical failure, V.J. Colangelo and F.A. Heiser, A Wiley Interscience Publications, 1974.

[5] Corrosion in power generating equipment, Ed. M.O. Speideland Andrejs Atrens, Plenum Press, 1983.

[6] Failure analysis of a turbine casing, report, NML CIEP, Dec. 1996.

[7] In-situ metallography at selected points of boiler and turbine assembly of unit-2 of SSTPS, NTPC, Report, NML, CIEP, Oct. 1996.