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FAILURE INVESTIGATION OF A BOILER PIPE

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Abstract

The damaged boiler pipe from the cochran horizontal pipe type boiler was investigated to study the cause of its failure. The damaged pipe having a through hole of about 4mm size was studied from both water and fire side with the help of visual inspection, physical measurements, optical micrograph, x-ray diffraction (XRD) and Electron probe microanalysis (EPMA). It was concluded that water side corrosion was more predominant than the fire side corrosion in reducing the thickness of the plate and eventually causing a through hole. The higher rate of corrosion from water side may be attributed mainly due to the presence of large amount of inclusions which led to preferential dissolution of matrix around them. The water side corrosion product was non adherent, fragile and powdery whereas fire side corrosion product was adherent.

Introduction

The boilers are the energy conversion systems where the heat energy is used to convert water into high pressure steam, which can further be used for running turbines, engines or other applications. The fuel used is fossil fuel which can be solid, liquid or gaseous in nature. Water is heated indirectly and hence transmission of heat takes place through the metallic element i.e., pipe or tube wall. This leads to the pipe material being subjected to high temperature corrosion on the fire side and aqueous corrosion on the water side.[1, 2, 3]

On fireside, there can be attack by fly ash as well as salt deposits like Na_2SO_4, V_2O_5 etc. These compounds are formed by the chemical reaction between the elements present in fuels (coal, oil or gas), air and environments during combustion. It has been found that Na_2SO_4 itself is not very aggressive at the operating temperatures of the boilers whereas the presence of small

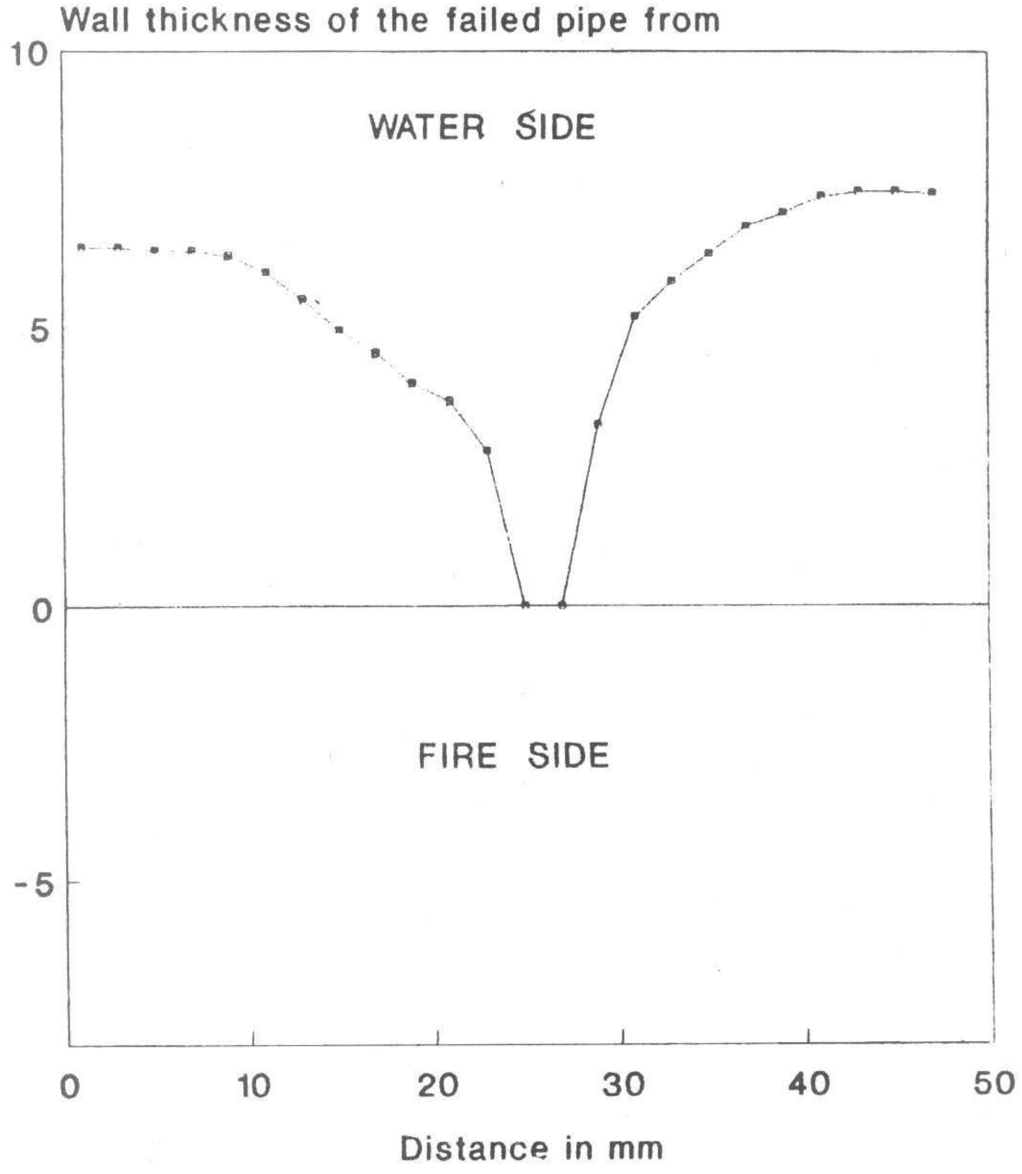

Figure - 1: Contour of the failed pipe from the water side amounts of chloride or V_2O_5 leads to more severe attack.[1,3,4]

On water side, the reaction between water and the pipe material gets accelerated due to higher temperatures. If the inclusions are present in the pipe material, they may provide the preferable areas of attack due to formation of anodic and cathodic sites leading to pitting type corrosion which is much more dangerous than the uniform corrosion. In boilers, there is a tendency of deposition of salts on the pipe surface on the water sides.[1,4]

If water is not properly treated and the boiler is not descaled at regular intervals, then these deposits on the water side may act as insulator thereby decreasing the heat transfer from fire side to water side, leading to generation of hot spots. At these hot spots, the dry as well as the salt corrosion will be accelerated due to generation of high temperatures.[5-9]

Most of the boiler failures are due to faulty operation or faulty selection of material because the designing aspects take care of pressure, temperature and other parameters with which the boiler has to run. If the failure takes place, it is very important to study the cause of failure, so that the modification may be done in the material or operation procedure or design, so that the long trouble free service life is guaranteed. The failure analysis will also help in fixing the responsibility for a mishap.[4,10]

This paper presents the results and discussion of the studies made on a failed boiler pipe material. This work involved examining both the surfaces water and fire side of the damaged boiler pipe taken from Cochran Boiler, by using optical microscope, XRD, SEM and EPMA.

Experimental Method

The corroded sample was taken from the Cochran Patent Vertical Multitubular Boiler which is made out of Seimens Martin mild steel, having chemical composition 0.11C, 0.42Mn, 0.13Si, 0.04S, 0.012P and balance Fe. The mild steel had UTS of the order of 28-30 TSI. The boiler was started in 1969 and the boiler pipe was damaged and replaced recently. The sample had a through hole.

The damaged pipe was cut and its thickness was measured by spherometer at a number of points in the region adjacent to the hole and a contour was drawn.

The sample was then polished to mirror finish by using various grades of silicon carbide papers and finally on polishing wheel using high grade alumina powder. The polished sample was then studied under metallurgical microscope for its microstructures. The sample was further examined on both sides by means of XRD, SEM and EPMA to study the corroded surfaces. Similarly a specimen of new pipe was polished and examined for comparison sake.

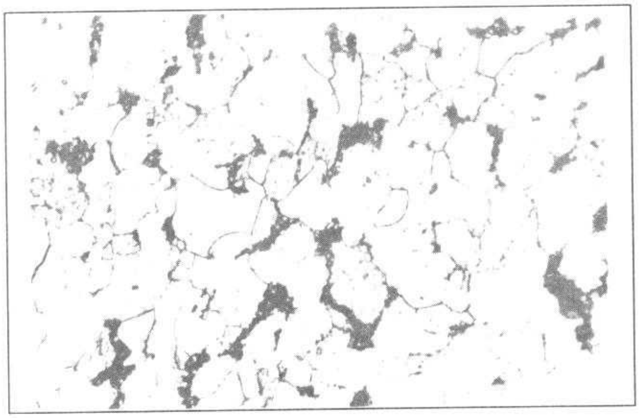

Fig. 2 : Microstructure of the sample of damaged pipe from water side

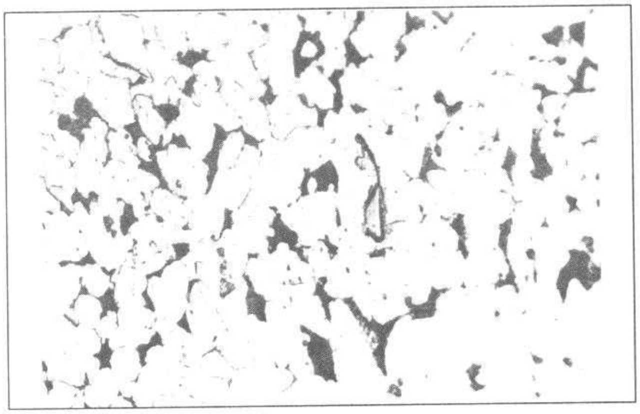

Fig. 3 : Microstructure of the sample of damaged pipe from the fire side

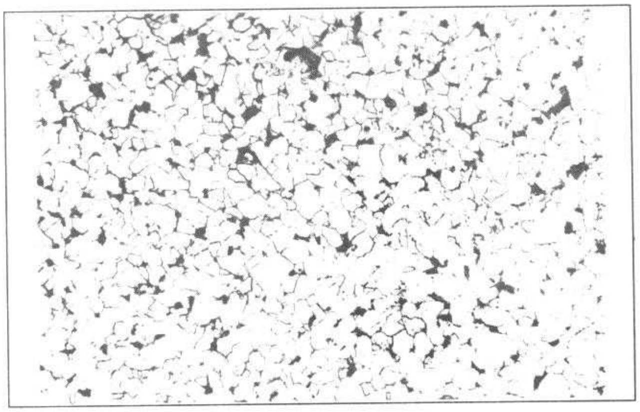

Fig. 4 : Microstructure of the sample of new original pipe

Experimental Results

Corrosion Mo-phology : The damaged pipe had an irregular shaped through hole and the region around the hole is wafer thin. The fire side scale was brown in colour and was quite adherent whereas the water side scale was reddish brown in colour and was quite fragile and powdery in nature.

The corrosion rate on the basis of total number of years of service given by the boiler pipe was 2.05×10^{-3} inch/year.

The contour of the damaged portion, obtained by measuring with spherometer on both sides, is given in Fig. 1. It shows the contour of the metal near the hole moving inwards from the water side.

Metallographic Studies : Fig. 2 reveals the microstructures of sample from water side consisting of ferrite and pearlite. The inclusions are present at the grain boundaries and the micropores are visible throughout the structures. Fig. 3 reveals the microstructures of sample from fire side consisting of ferrite and pearlite. The grains are distorted but presence of black inclusions is also predominant. Fig. 4 shows the microstructre of the new original pipe revealing the inclusions around the grain boundaries.

Scanning Electron Microscopic Studies : Fig. 5 shows the SEM micrograph of the sample from water side having an irregularly shaped through hole and the cracks running outwards. Fig. 6 shows the magnified area of the periphery of the hole with a crack. Some transgranular cracks are also visible. Fig. 7 gives clear indication of the presence of inclusions. Fig. 8 shows the SEM micrograph of the sample from fire side. This clearly reveals that the scale has got cracks and some areas of the scale have spalled. Fig. 9 is the SEM micrograph of the new pipe showing slag stringer inclusion.

X-Ray Diffractograms : XRD data of the water and fire side of the sample are given in Table 1.

Table - 1
Identification of the consituents of the failed boiler pipe

Material	Constituents Identified by XRD
Failed pipe from water side	α - Fe
Failed pipe from fire side	NiFe, Cr_2O_3, Fe_2O_3, and FeO

Electron Probe Microanalysis: The EPMA data for water and fire side are given in Tabes 2 and 3.

Table - 2
Electron Probe Microanalysis of Failed Pipe from Water Side

Element	Mn	Si	Cr	Mo	S	Fe	Co	Ni
Wt%	0.64	2.18	0.05	0.82	2.42	93.69	0.13	0.03

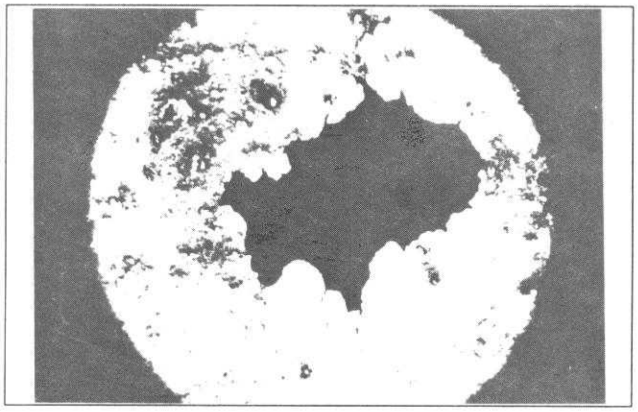

Fig. 5 : SEM Micrograph of the sample of damaged pipe from water side(X10)

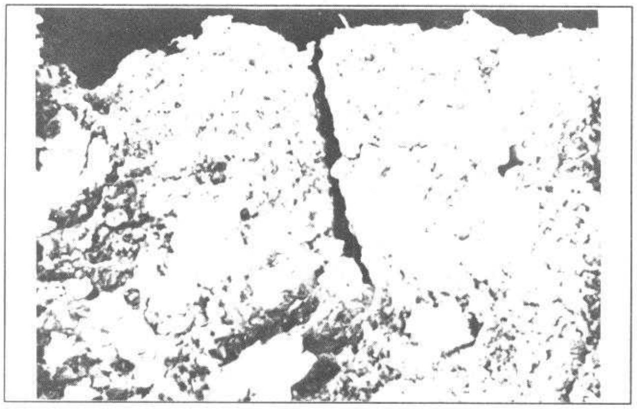

Fig. 6 : SEM Micrograph of the sample of damaged pipe from the fire side (X160)

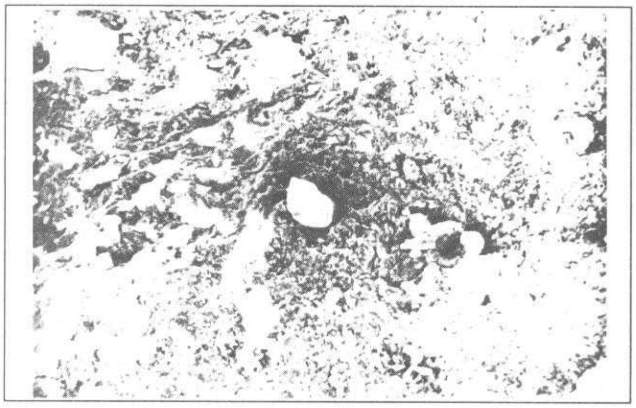

Fig. 7 : SEM Micrograph of the sample of damaged pipe from the fire side (X80)

Table - 3
Electron Probe Microanalysis of Failed Pipe from Fire Side

Element	Mn	Si	Cr	Mo	V	S	Fe	Co	Ni
Wt%	8.86	0.20	2.22	40.64	0.04	13.53	3.59	29.45	1.43

Discussion

The boiler pipe failed miserably due to combined effect of corrosion from both water and fire side. It is evident in Fig. 1 that damage has occurred mainly from water side. This may be attributed to the nature of water side scale being fragile and powdery hence it spalled and corrosion proceeded inside the material deeper and deeper till the pipe failed. The fire side scale was compact and hence was protective.

Fig. 2, 3 and 4 show the presence of inclusions and the pores. The large number of inclusions present may act as differentially charged electrodes as compared to matrix thereby forming a differential cell which leads to higher rate of dissolution by aqueous corrosion. The micropores in the ferrite matrix cause pitting type corrosion. The SEM micrographs 5, 6, 7, 8 and 9 also confirm this mechanism of corrosion by showing the transgranular cracks in the scale. Some areas of the scale being spalled and there is clear indication of inclusions.

XRD data of the water side scale indicate only the presence of Fe which may be attributed to the non adherent powdery scale being removed during handling. XRD data of the fire side scale indicate the presence of mainly Fe_2O_3 and FeO with some indication of Cr_2O_3 and NiFe phase.

The composition of analysis of the wate side at points near the edges of the hole shows the presence of mainly Fe with some amount of Si, Mo, S, Co and Ni. The composition of points away from the edges shows slightly higher content of Si and S. The amount of S at one point is very high and this suggests the presence of sulphide inclusion and the amount of Si is high which also indicates the presence of Silicates (Table. 2). A large amount of sulphur coupled with Mo, Cr, some Mn and very small amount of Fe can be seen in Table. 3. This indicates the presence of sulphide inclusion in the area near the hole. Also there is indication of presence of intermetallic compounds Fe, Mn, Mo and Fe, Ni, Mn. The presence of large amount of S and P in the scale may be attributed to the burning of coal having higher amount of S and P.

Conclusions

The mild steel boiler plate from Cochran Boiler failed due to the presence of large amount of inclusions.

The failure analysis shows that the water side corrosion is more predominant than the fire side corrosion.

The water side scale was powdery, fragile and non adherent whereas the fire side scale was compact and protective.

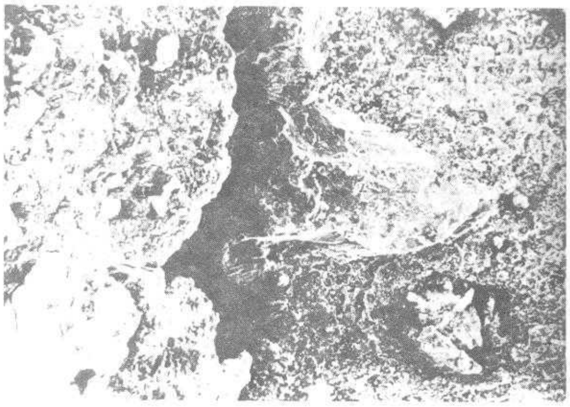

Fig. 8 : SEM Micrograph of the sample of damaged pipe from the fire side (X80)

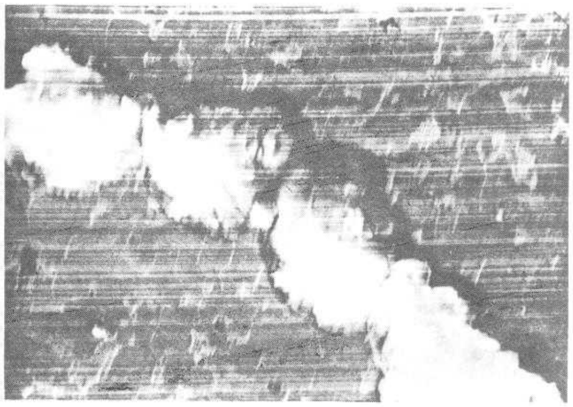

Fig. 9 : SEM Micrograph of new original pipe (X320)

The life of the boiler plate can be increased by substituting the mild steel material with some high alloy steels and super alloys so that the alloying elements may provide passivity.

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