COMBINATION OF NDE TECHNIQUES AND STRAIN MONITORING OF A STEAM PIPELINE

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Thermal power plants and refineries around the world have typically been in operation for many years and are approaching, or have exceeded, their design life. Their components such as boiler tubes, headers and steam pipes operate in a complex environment involving high temperature, pressure and corrosive atmosphere. Several damage mechanisms such as creep, fatigue, corrosion, oxidation, occur depending on the operating conditions. Beyond a critical temperature, creep acts as the dominant damage mechanism. The costs of replacement are high and there is no good economic or engineering reason to scrap such installations if they are in sound condition and if their safe operation can be extended. Hence, it has become an accepted procedure that such plants should be assessed and operation continued as long as it is safe to do so. In many service conditions, creep damage may occur at critical positions such as pipe bends or welds, which can result in failures at these locations. Therefore, it is very important to find out these locations with severe damage for predicting the service life of whole pipelines and making reliable maintenance strategies for the piping systems operating at high temperatures. NDE techniques (e.g. hardness testing, ultrasonic tests and metallographic examination) combined with strain monitoring may be a good solution to provide an effective maintenance planning to components subjected to creep conditions. In this paper, a steam pipeline was investigated. In order to detect the most critical areas of the component, a finite element analysis was done considering the operating pressure and temperature. After that, surface replication and hardness test were made at the critical region. These tests showed cracks in the pipeline surface and hardness values were below the specification of the material. Strain and temperature monitoring have also been used. The results showed a strain increase during the pipeline operation at high temperature, an indicative of creep damage.

INTRODUCTION

Power plants components have finite life due to prolonged exposure to high temperatures, stresses and harsh environments. Several natural ageing processes such as creep, corrosion and fatigue. occurring during long term operation are responsible for accumulating damages in the tubes. The effective strength, i.e. load bearing capacity of the tubes due to microstructural damages decreases. Improvements in the efficiency of power plants result essentially from increases in the steam pressure and temperature which lead to higher thermal and mechanical loading of the pipe components. In order to quantify the loading and the material degradation of the pipe components modern performance monitoring methods are essential. Aging and cyclic operation regime of thermal power plants point the need of life assessments of their components to ensure continued safe operation or recommend repairs and modifications that allow operation for a pre-determined period. [1,2]

Remaining life assessment of aged power plant components in the present highly competitive industrial scene has become necessary for both economic and safety reasons as most of the power plants are over 25 years old. Many methods of assessment are used, and several procedures and methodologies have been adopted. It is particularly important that potentially critical components and parts be identified, so that detailed examination can be conducted as required. Areas of particular concern are steam tubes, superheater tubes, headers, and steam transfer pipes. Bends and welds (and, in particular, dissimilar metal welds) are areas where experience has shown that damage may occur preferentially [3]. Therefore, it is important to detect material degradation by means of non-destructive techniques, like visual examinations, hardness test, magnetic particle inspection or metallographic examinations.

These tests carried out on the tubing surfaces can give some idea about the health of the component. Non-destructive tests results, however, cannot predict the creep deformation behavior of the service-exposed tubes. The use of strain monitoring can complete the component's inspection. This method has been widely used as a direct measurement of performance both in laboratory experiments, in full size pressure vessel tests and for in-service monitoring [4]. In field, components the strain rate may be obtained directly from installed strain gages.

This work presents a case study of combination of NDE techniques and strain and temperature monitoring in the critical region of a steam pipeline to evaluate its expected life. The strain gages were installed directly on the piping at the positions of higher stresses, where higher strains are expected. The higher stress position in the steam pipeline was identified by finite element analyses.

EXPERIMENTAL PROCEDURE

The steam pipeline characteristics are given in Table 1. Figure 2 shows the schematic drawing of the hot reheat steam piping.

Table 1
Material specification, dimensions and service condition of the hot heat steam piping of a thermal power plant

Steam piping	Material	Operating steam pressure (ºC)	Operating steam pressure (MPa)	Thickness (mm)	Outer diameter (mm)	Service-exposed (hours)
Hot reheat	2,25Cr-1Mo	536	4,65	20	419	100,372

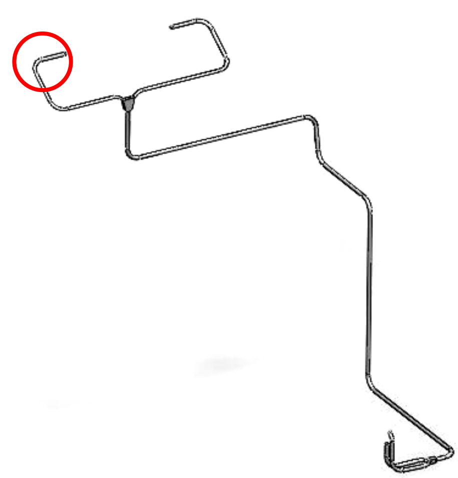


Figure 2 – General view of hot reheat steam piping

One of the critical positions resulting from the finite element analysis refers to a curve next to the outlet header (highlight). This region was tested by replica examination and hardness tests. The preparation for evaluation of the microstructure included several grinding steps followed by mechanical polishing and surface etching. Onto this etched surface, a sheet of acetate type film is placed and partially dissolved with a solvent. The etched structure is then imposed on the acetate film as a replica image. The acetate is removed from the surface and secured to a glass microscope slide. Hardness was measured on the polished surface using Krautkramer hardness tester, 2.4 V DC, Vickers scale.

A pair of strain gages was installed, by spot welding, directly in the pipe curve. Figure 3 shows a strain gage couple welded in the steam piping. The temperature monitoring is performed by thermocouples installed next to the gages.

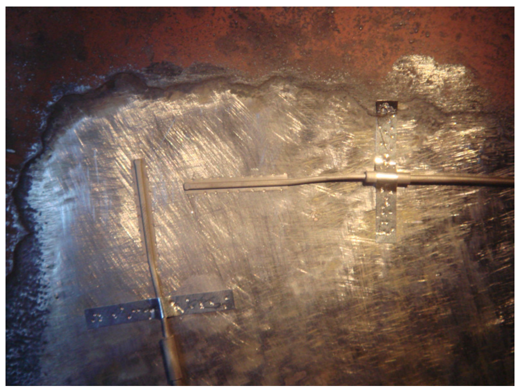


Figure 3 – Strain gages welded in hot reheat steam piping

THE MONITORING SYSTEM

The system used, named Monitermo, was developed at CEPEL, and is based on WEB technology, Postgres database and Field Point platform, from National Instruments, for data acquisition. The hot reheat steam piping has 43 temperature points and 16 strain gages welded in critical locations. Pressure data collected at the entry are also monitored. Data are stored periodically in a database that can be accessed via internet. Real time data (on-line) can also be observed on the net, since they are renewed every minute.

In Figure 1a, it is possible to see an example of the Monitermo system screen, where strain versus time has been monitored during 3 days. Figure 1b shows another screen example where is possible to see the temperature and strain in each monitored part of the piping. Temperatures lower than 530^{o}C are shown in a green box, temperatures higher than 555^{o}C are presented in a red box. Strains lower than 5,000με are shown in green, from 5,000 to 8,000με are shown in yellow and above 8,000με, red. The red box works as an alarm telling the engineering group that the piping is working in non secure conditions.

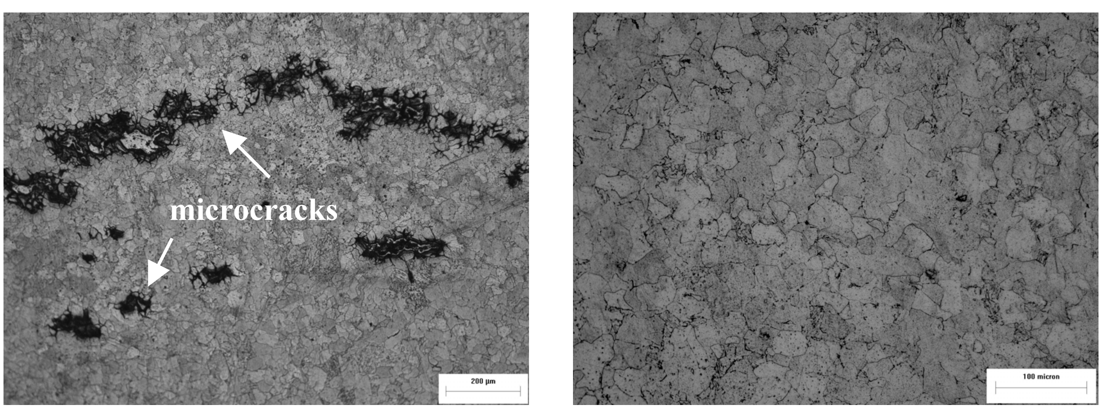
(a) **(b)**

Figure 1 – Screens of Monitermo monitoring system: (a) strain versus time; (b) strains and temperatures in a section of the steam piping

RESULTS AND DISCUSSION

The average value of Vickers hardness was 132 HV. This value is close to the lower limit of nominal hardness for the 2.25Cr-1Mo steel, where the hardness varies from 130 to 195 HV, depending on the type of thermomechanical processing and heat treatment given to the alloy [5].

The curve microstructure consists of ferrite with spheroidized carbides in stage C of Toft and Marsden [6] microstructural degradation classification. Additionally, many creep intergranular cracks were observed, as shown in Figure 4.



100x **240x**

Figure 4 – Replica examination of critical region of hot heat steam piping

In Figures 5 e 6, it is possible to see the strain and temperature monitoring results. Figures show Monitermo system screens, where strain versus time (Figure 5) and temperature versus time (Figure 6) have been monitoring during one month. In Figure 7, it is possible to see the strain monitoring results in another monitoring point, which one not presented microstructural damages. As can be seen, the strain accumulated at this point is less than critical region.

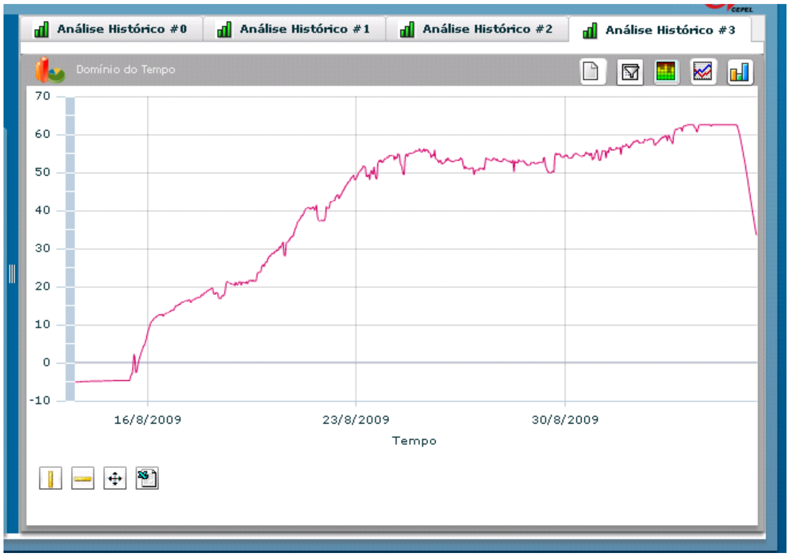


Figure 5 - Screens of Monitermo monitoring system: Strain versus time (days) at critical region.

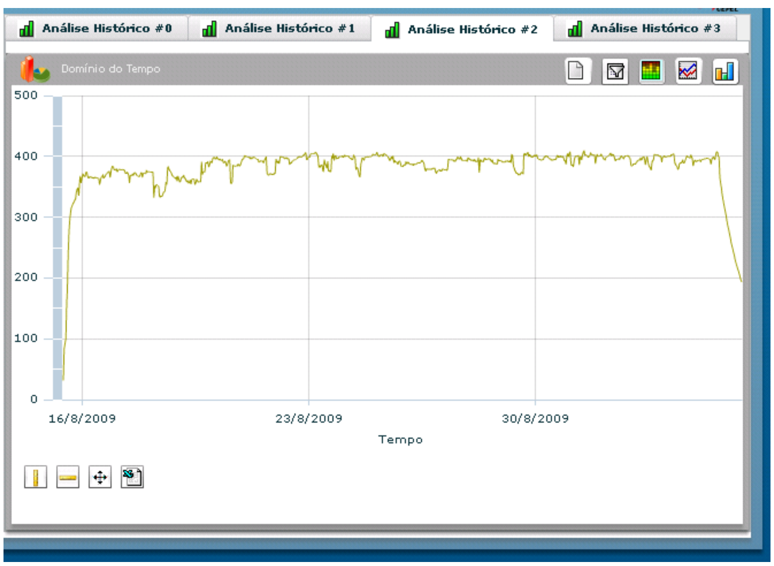


Figure 6 - Screens of Monitermo monitoring system: Temperature versus time (days).

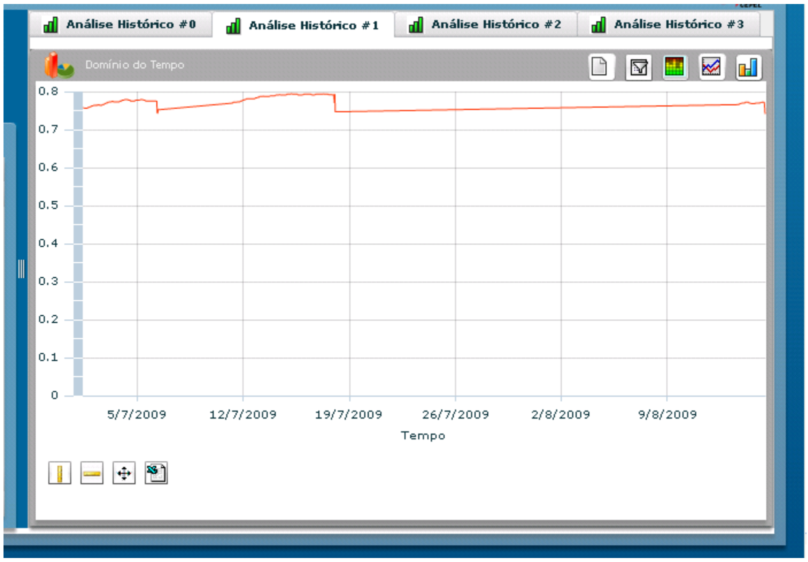


Figure 7 - Screens of Monitermo monitoring system: Temperature versus time (days) at not critical region.

CONCLUSIONS

Integrity assessment of engineering components in power plants and process industries has attracted global attention from the viewpoint of safety and economy for their optimum utilization. The great importance and utility of strain monitoring and non-destructive techniques for complete evaluation of power plant components has been emphasized.

The use of a monitoring system in real time gives a faster response, allowing more precise monitoring of deformations changes in steam pipelines. Also, it can be used by the maintenance team as a powerful tool for decision making.

The present paper shows a strong correlation between the monitoring data (strain and temperature) and non destructive techniques.

In the future, a work on the optimization of these techniques will be done in order to calculate the residual life to the component due to creep damage.

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