

Damages That Occur at Vital Components of the Thermal Power Plant System Detected by NDT Testing

Srđan Bulatović*, Vujadin Aleksić*, Ljubica Milović**, Bojana Zečević***

* Institute for materials testing, Bulevar vojvode Mišića 43, Belgrade, Serbia

** University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia

*** Innovation Centre, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia

Abstract – Continuous exploitation in very harsh environmental conditions can lead to relatively frequent damages of steam line system. High place among the causes of these damages takes inadequate exploitation and maintenance. This paper describes damages and failures of steam line and provides an overview of NDT testing in order to determine the cause of steam lines failure in thermal power plants. This method may be applied to similar structures and its application in preventive maintenance would help extend the life of steam pipes. The results presented in this paper and conducted research projects allow us to analyze the behavior of supporting elements of steam line in order to determine changes in mechanical properties of materials.

Index Terms – non-destructive testing (NDT), damages, steam line

I. INTRODUCTION

High-pressure pipelines and steam lines and are vital parts of the thermal power plant system. In general, they are the connection between the boiler and turbines in power plants or boilers in power stations and customers in heating plants. They are critical components in power plants and heating plants and have a significant impact on the reliability and availability of power plants and heating plants. Continuous mining in very hardworking conditions can lead to relatively frequent system steam line failure. Damages on steam line elements may appear well before it is projected, and not just as a result of internal pressure and temperature, but also as the consequence of the loads that occur due to poor design and inadequate maintenance. Also, damages of steam line elements may appear because of numerous turns and starts of the boiler as well as contempt of start diagram. Failures of steam lines, other than direct material damage, could jeopardize the safety of personnel and equipment. High place among the causes of these failure takes inadequate operation and maintenance. Leaking of steam lines caused by creep material is expected if number of hours spent in operation is higher than appointed number of hours. RA, RB and RC line thermal units 1 to 5 length of 200-300 m, capacity 300-500 t / h, thermal block serving at TPP "Kolubara A"-Veliki Crljeni. During its operation there were a relatively frequent delays caused by defects of supporting structure [1,2], and in extreme case even failure or steam line leaking, which is usually explained by gaps in technology development and mishandling.

II. TECHNICAL DIAGNOSTICS

During the operation period comes to fatigue of steam line components. Degradation of material properties and deformation of elements can be accelerated due to the exploitation and repair errors, that's why periodic or continuous diagnostic measurements, conducting periodic tests and data collection programs defined by [1,2], are needed. In this way, processes that could lead to the creation of system damage are under systematic control, what is also the legal obligations imposed by the regulations, directives and harmonized standards [3,4,5]. Properly conducted technical diagnostics protects parts of the steam line from accident, and also ensures safer conditions for employees as well as rational techno-economic exploitation and maintenance. Technical diagnostic of steam lines must be based on three basic principles:

- measurements and volume of tests shall be in accordance with the program of research [1] and an expert knowledge of steam line structure;
- tests and measurements must be performed in accordance with special procedures, using appropriate equipment and qualified personnel;
- test results should be presented in such way that the conclusions include steam line operating conditions, the availability of the test team and staff with appropriate experience and knowledge in the field of design, construction, installation, operation, maintenance, reliability, fracture mechanics.

III. NDT TO DETERMINE CAUSE OF STEAM LINE FAILURE

For purpose of determining the causes of failure it is necessary to make steam line 100% visual inspection, MT, PT, UT, HT, REP. If necessary, other tests that would give us a reliable and useful results to determine causes of steam line failure could be done. Figure 1 shows the possibility of establishing some damage using NDT methods in the life of the steam line.

Visually optical control (VT) - is used to detect defects that are visible on the surface of the steam line from the outside or inside of the tube. It applies regardless the method to be applied after it, because it is possible to detect errors, such as in our case, and avoid the use of other, more costly methods of NDT. It is often used for the selection of critical areas of the facility for the application of other NDT testing methods.

At the same objects it may be performed multiple times (eg, before and after cleaning, or before and after the execution of corrosion protection, etc.).

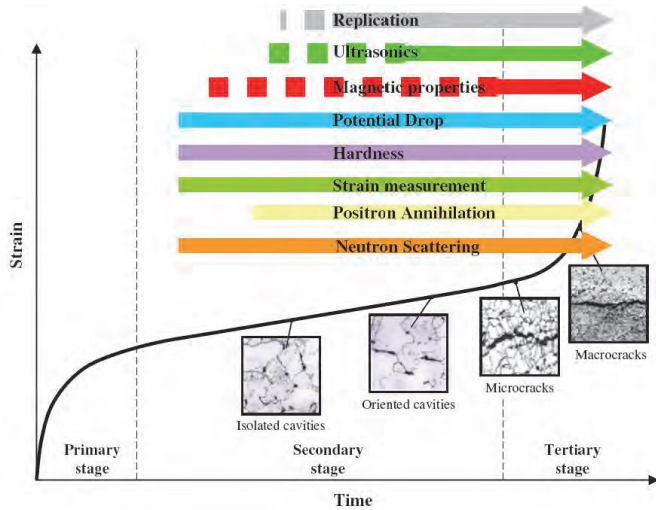


Figure 1. Application of NDT methods in detecting defects in the life of the steam line [6]

Control of the inside of the tube (endoscopy) allows optical access to the interior of steam lines. It is performed using an endoscope, and as a result we get control of video or photograph controlled inner surface, figure 2.



Figure 2. Photo of interior surfaces steamline

Magnetic particle testing (MT) - Magnetic particle Inspection (MPI) is a nondestructive testing (NDT) process for detecting surface and shallow subsurface discontinuities in ferromagnetic materials such as iron, nickel, cobalt, and some of their alloys. The method is based on emphasizing the stray magnetic flux caused by the presence of surface or subsurface defects like cracks, notches, inclusions and other types of sharp or planar defects. Advantage of the method is that it requires a moderate cost, and if done correctly, you get a very good sensitivity for the detection of surface defects. The disadvantages of this method is that it could only be applied to ferromagnetic materials as well as the potential need for degaussing after completing the testing. The method is commonly used for the detection of cracks and other defects in weld joints, castings and forgings.

Ultrasonic testing (UT) - Ultrasonic testing is often performed on steel and other metals and alloys. It is used in many industries including steel and aluminium construction, metallurgy, manufacturing, aerospace, automotive and other transportation sectors. The method is based on detecting changes in acoustic resistance due to the presence of cracks, voids, inclusions, and general physical separation in the material. The advantage of the method is that is also applicable to the thicker material, it is excellent for detecting and locating cracks and other defects, and it is suitable for automation. The biggest disadvantages are the need for a medium on the surface to be tested (or complete immersion of testing item in contact medium), as well as the request that surface on which the probe is moving is relatively smooth (cleaning needs, grinding the metallic shine). The most common application is to detect and precisely determine the position of defects in plate, welded joints (and butt and fillet) steel castings and forgings (if their geometric configuration allows). Application of this method for testing materials with high attenuation of ultrasound energy (for example, high alloyed austenitic steels, cast bronze) is difficult and can be done only under special circumstances.

Hardness testing (HT) - For evaluation of properly applied heat treatment after welding, hardness testing of the base metal, HAZ and weld materials are performed. At the same time, hardness and hardness differences must be within the limits of applied materials. In Table 1. the recommended values of hardness [7] of materials that are commonly used to produce steam line are shown.

Table 1. Values of hardness of materials

Materials	Hardness [HV]		
	Base materials	Weld joint	Heat Aected Zone (HAZ)
1.5415 15 Mo3	140-190	≤260	320
1.7335 13CrMO44	135-185	≤270	320
1.7380 10CrMo910	140-190	≤280	320
1.7715 14MoV63	145-190	≤280	320
1.7745 15CrMoV510	140-215	≤280	320
1.4922 X20CrMoV12-1	215-265	≤300	350
1.4903 X10CrMoVNb91	190-260	≤300	320

Method of replica testing (REP) - Metallographic examination, figure 3, the surface layer of material of pipe bends, weld joints and pipes on the old steam pipe RA 10 block A1, is conducted by the method of nondestructive testing of materials, using metallographic replica, according to [8].

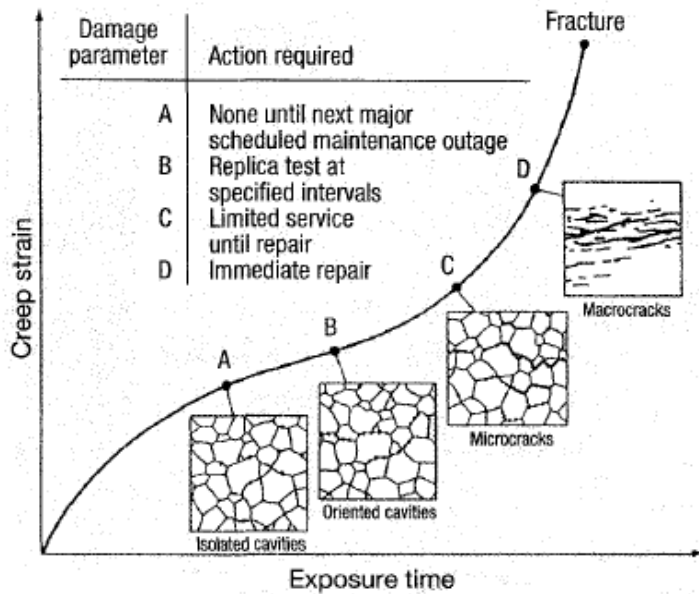


Figure 3. Overview of possible damage to the established method of replica [9]

In order to detect the microstructure of materials, adequate preparation is made of tested surfaces, and that included cleaning and a range of fine sanding operations. After the final polishing and cleaning, the test surfaces were eroded with appropriate reagent, ie. 4% nital.

IV. DETERMINING DAMAGES

Me

Structures of the steam line is exposed to the low cycle fatigue loads. This load caused a fatigue damage of pipes and leaking of steam lines on observed object, figure 4, which was confirmed by visual inspection.

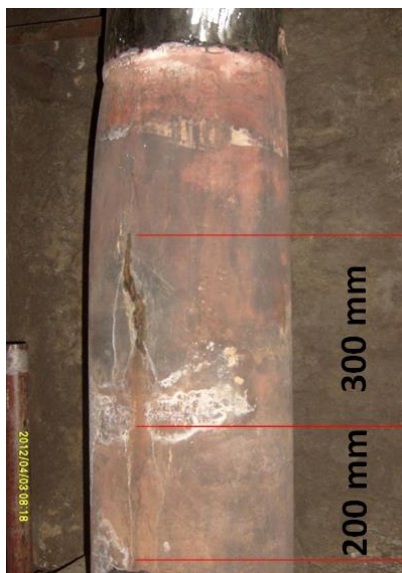


Figure 4. Determination of damage by visual inspection

NDT methods for testing the steam pipeline section and supporting structure before and after damage are used.

Assessment of the microstructure of the materials that are used for tube bends and welded joints and creep damage level are made according to the recommendations for the assessment of the microstructure [10].

The degree of quality degradation of the microstructure of the old pipe was determined according to the recommendations of the European Commission for assess the remaining life of the microstructure [11].

Figures 5 and 6 show the typical microstructure of the surface layer of the old pipe taken from a replica.

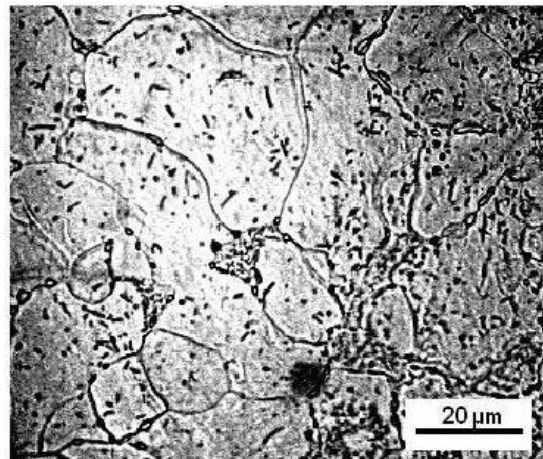


Figure 5. Replica RA10-R1

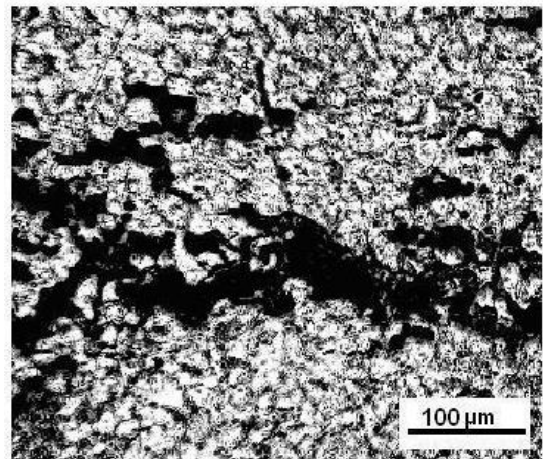


Figure 6. Replica RA10-R3

In microstructure of tested replica taken from the surface of the material of the old pipe a certain degree of quality degradation was observed which is caused by initial spheroidization and carbide precipitation per grain boundary in places with the presence of globular pearlite- the level of quality degradation of microstructure B/C, according to [11]. Products of corrosion and corrosion damage in spots are present in the microstructure of tested replica.

V. ANALYSIS OF DAMAGE

We analyzed the damaged parts of steam line, to determine the cause of the problem, which is a process that requires a systematic approach. Test results of NDT methods contribute to the knowledge of damage formation and allow us to determine the cause of steam line failure. Based on the research of failure and causes of failure of certain components of steam line using method FMEA and reliability parameters obtained from the analysis of the data collected in real operating conditions, a system of continuous diagnosis could be established.

Stress analysis [12,13,14], damage and fractures [15,16] welded joints of steam line elements provide important directives for the development of design methods and construction elements of the steam line to improve the properties of existing materials and their processing technologies. Also, by analyzing fractures, the development of new technical solutions and methods of testing is enabled [17] in the prototype stage. It is necessary to take into account the risk analysis and structural integrity [18,19], as a new approach to the assessment of structural integrity.

VI. THE DATABASE INFORMATION

Load data, the characteristics of the base material and its welded joints, technology development, technical and physical characteristics reported fractures data and preventive measures provided for damage and destruction are obtained from the databases. Database of implemented testing [2] and research [20] on the appropriate structures allows us to analyze the behavior of supporting elements of steam line in order to determine changes in mechanical properties of materials. Load data, as well as the characteristics of the base material and its welded joints, technology development, technical and physical characteristics of the recorded fracture and destruction are inserted into the appropriate database. Reliable assessment of the integrity of the observed elements, could be made only after creation of adequate database and the basis for the development of computer programs [21]. Supporting software packages would allow more efficient use of the database, the analysis of some influencing factors, and the search of alternative solutions in all phases of design and development of construction

VII. CONCLUSION

Only by examining the construction of steam line operating conditions it is possible to assess their condition completely. During examination period the necessary data are obtained to determine the quality and structural integrity assessment and evaluation of the impact of the elements on the capacity and is given the necessary data to establish the joint work of devices and structure of steam line.

The results presented in this paper and conducted research projects allow us to analyze the behavior of supporting elements of steam line in order to determine changes in mechanical properties of materials.

ACKNOWLEDGEMENT

This research is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract No. 451-03-68/2022-14/200012).

REFERENCES

- [1] KLBA-M9-013: *The test program of the technological metal machine part*, TEK A, June, 2001.
- [2] *Reports on NDT testing methods of steam line at the Kolubara A*, Institute IMS, 2000. -2012.
- [3] *Regulation on the technical requirements for the design, development and conformity assessment of pressure equipment* (Sl. glasnik RS no. 87/2011).
- [4] *Regulation on pressure equipment inspections during the operation* (Sl. glasnik RS no. 87/2011).
- [5] Pressure Equipment Directive (PED 97/23/EC).
- [6] Sposito G. et al.: *A review of non-destructive techniques for the detection of creep damage in power plant steels*, NDT&E International, 2010, 43, 555.
- [7] VGB-R 508 L : Richtlinie für die Herstellung und Bauüberwachung von Rohrleitungsanlagen in Wärmekraftwerken.
- [8] SRPS ISO 3057/2011: Non-destructive testing -- Metallographic replica techniques of surface examination (identical with ISO 3057/1998).
- [9] SPRINT SP 492.
- [10] VGB - TW 507 e: Guideline for the Assessment of Microstructure and Damage Development of Creep Exposed Materials for Pipes and Boiler Components [Edition 1992].
- [11] ECCO Recommendations - Volume 6: Residual life assessment and microstructure [Issue 1].
- [12] Jakovljević A.: *Numerical stress analysis of high pressure steam lines in power plants*, Structural integrity and life, Vol.7, No1, 2007, pp. 13-20, UDK 620.169.1:621.643.023-988.
- [13] Petronić S.: *Comparative Analysis of the Design Stress According to Different Regulations on Pressure Equipment*, Structural integrity and life, Vol.12, No2, 2012, pp. 143-148, UDK 66-988(083.133).
- [14] Petronić S., Grujić B., Balać M.: *Test Pressures and Stresses for Pressure Vessels According to New Regulation 87/11*, Structural integrity and life, Vol.12, No3, 2012, pp. 209-213, UDK 620.1:66-988.
- [15] Milović Lj.: *Significance of cracks in the heat-affected-zone of steels for elevated temperature application*, Structural integrity and life, Vol.8, No1, 2008, pp. 55-64, UDK 621.791.051:669.14.
- [16] Milović Lj., Vuherer T., Radaković Z., Petrovski B., Janković M., Zrilić M., Daničić D.: *Determination of Fatigue Crack Growth Parameters in Welded Joint of HSLA Steel*, Structural integrity and life, Vol.11, No3, 2011, pp. 183-187, UDK 620.172.24: 669.15, 620.172.24:66-988-112.81, 621.791.05:539.4.013.
- [17] Gubelj N.: *Application of Stereometric Measurement on Structural*, Structural integrity and life, Vol.6, No1-2, 2006, pp. 65-74, UDK 620.169.1.
- [18] Đorđević P., Kirin S., Sedmak A., Džindo E.: *Risk Analysis in Structural Integrity*, Structural integrity and life, Vol.11, No2, 2011, pp. 135-138, UDK 65.012.32.
- [19] Kirin S., Jovanović A., Stanojević P., Sedmak A., Džindo E.: *Risk Analysis in Structural Integrity – Application to a Large Company*, Structural integrity and life, Vol.11, No3, 2011, pp. 209-212, UDK 65.012.32.
- [20] Sedmak S., Radaković Z., Milović Lj., Svetel I.: *Significance and Applicability of Structural Integrity Assessment*, Structural integrity and life, Vol.12, No1, 2012, pp. 3-30, UDK 620.172.24, 620.169.1, 539.42.
- [21] Popović A., Marković M., Panić B., Nikolić M.: *Data Acquisition and Processing*, Structural integrity and life, Vol.6, No1-2, 2006, pp. 53-64, UDK 620.17.05:004.

AUTHORS

Srđan Bulatović, PhD, Institute for materials testing-Institute
IMS, srdjan.bulatovic@institutims.rs,
Vujadin Aleksić, PhD, Institute for materials testing-Institute
IMS, vujadin.aleksic@institutims.rs
Ljubica Milović, PhD, University of Belgrade, Faculty of Technology
and Metallurgy, acibulj@tmf.bg.ac.rs
Bojana Zečević, MSc, Innovation Centre, Faculty of Technology and
Metallurgy, baleksic@tmf.bg.ac.rs

Correspondence Author – Srđan Bulatović, PhD, Institute for
materials testing-Institute IMS, srdjan.bulatovic@institutims.rs,
+38165/8898562