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ANALYSIS OF THE STEAM LINE DAMAGES

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ABSTACT: The methodological approach to the analysis of damage to determine the cause of failure and to repair the damage has been shown using the example of leakage and damage of a steam line for live-steam in thermal power plants and heating plants. The access presented may be applied to similar structures, and its application in preventive maintenance contributes to extension of the exploitation life of the steam lines.
Keywords: steam line, damage, damage analysis, repair

1. INTRODUCTION

Due to the extremely strict demands related to the achievement of the designed capacity and reliability in operation, design and calculation of vital parts of the steam lines is a complex task and is subject to the Regulations on the technical requirements for the design, construction and assessment of harmonization of pressure equipment. During the exploitation, inspections of the steam lines according to the Regulations on the examination of pressure equipment during exploitation life are planned. Leakage of the steam lines induced by material creep due to a large number of hours in exploitation exceeding the prescribed number of hours is expected consequence. The continuous exploitation without the regular and emergency inspection prescribed by the Regulations may lead to frequent failures of the steam-line systems and unnecessary costly repairs.

In addition to direct material damage that they may induce, steam line failures can also affect the safety of personnel by significantly endangering it. Besides, unexpected delays in exploitation induce the damage resulting from the system downtime, which is usually much higher than the direct damage. High place among the causes of the aforementioned failures takes inadequate exploitation and maintenance.

2. DETECTION OF DAMAGE

The structure of the steam line is exposed to the low-cycle fatigue loads. Such a load caused fatigue fracture and leakage of the steam line for live steam at RA 10, TPP Kolubara A, Table 1, which was determined by visual examination, Figure 1.

Table 1. Technical Data on the Steam Line with Detected Damage

Stated pipe material:	15128.5
Steam line in exploitation:	160000 of operating hours
Operating pressure:	75, bar
Operating temperature:	540 , °C

The parts of the steam line in front of and behind the damaged part were tested using the NDT methods, Figure 1. The results showed that there were no damages on tested parts of the steam line.

In the microstructures of tested replicas taken from the surface of the material of the damaged pipe a certain degree of quality degradation was observed, induced by the initial spheroidization and precipitation of carbides at the grain boundaries, with presence of scattered globular perlite - level of qualitative degradation of the microstructure B/C. [2]. The assessment of microstructure of the material of pipe elbows and welded joints and the level of creep damage on undamaged part of the steam line was made according to the recommendations for the assessment of microstructure [3].

3. DAMAGE ANALYSIS

In order to analyze the damage and determine the cause of leakage of the steam line for live steam, line RA 10, TPP Kolubara A, two parts of the pipe Ø 273x25 mm, sampled from the same pipe of the leaking steam line, were submitted for examination. Namely, the pipe part with damage 1080 mm-long (1) and the pipe part without damage approx. 1260 mm-long (2), Figure 2, were submitted. From the pipe samples submitted the specimens and raw parts were made for testing, sampled from the positions defined in Figure 2.

a) external part b) inner part

Figure 1. The Appearance of the damaged part of the steam line

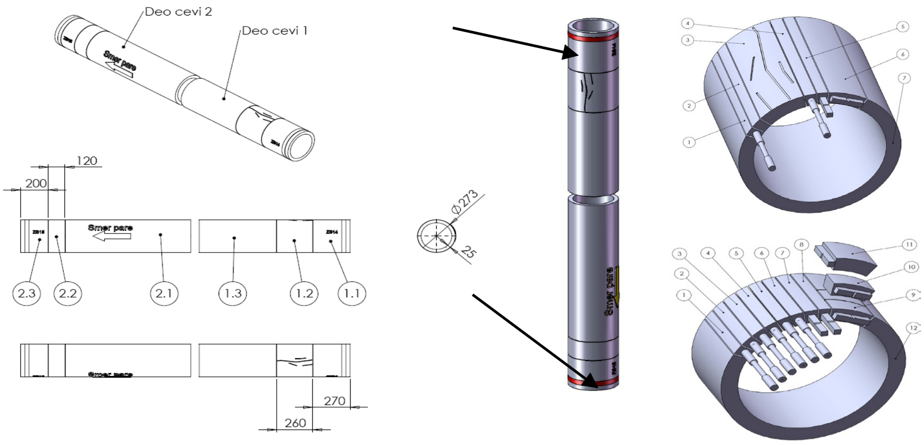

Figure 2. Positions of Annular Segments and Test Specimens

Testing of the chemical composition, structure of the materials of both damaged and undamaged pipes and mechanical properties as well was conducted. Specimens and raw parts are marked numerically with the following meaning: first digit: Number of the pipe (1-damaged; 2-undamaged); second digit: Mark of the position of the annular segment cut from the pipe, intended for manufacture of the specimens; third digit: Mark of the position of the longitudinal segment of the annular pipe section, from which concrete specimen was made; fourth digit: ordinal numeral of the specimen from the same section.

4. CHEMICAL COMPOSITION AND MICROSTRUCTURE TESTS

Table 2 gives the standard chemical composition of the stated pipe material for the steam lines [1, 4]. The raw part sampled from the damaged part of the pipe was subjected to the analysis of chemical composition using quantitative spectrophotometric method, and the results of the analysis are given in Table 3.

Table 2. Chemical Composition of the Material, 15 128.5 (ČSN), 14MoV6-3 (DIN)

Chemical Composition, %											
C	Mn	Si	Cr	Mo	V	P	S	Al	Ni	Ti	W
0.10	0.45	0.15	0.50	0.40	0.22	max	max	max	/	/	/
0.18	0.70	0.40	0.75	0.60	0.35	0.040	0.040	0.025			

Table 3. The Results of Chemical Analysis of the Material (Pos. 1.2.6)

Chemical Composition, %											
C	Mn	Si	Cr	Mo	V	P	S	Al	Ni	Ti	W
0.234	0.665	0.253	0.155	0.125	0.004	0.012	0.009	0.026	0.121	0.004	0.063

Table 4. The Results of Chemical Analysis of the Materials (Pos. 2.2.8)

Chemical Composition, %											
C	Mn	Si	Cr	Mo	V	P	S	Al	Ni	Ti	W
0.20	0.72	0.29	/	/	/	0.010	0.022	/	/	/	/

Analysis of the chemical composition by gravimetric and volumetric methods was conducted on the raw part sampled from the undamaged part of the pipe, and the results of the analysis are given in Table 4.

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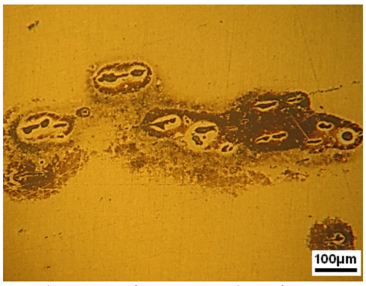
Table 5. The Results of Testing of Vickers Hardness (HV1) by Applying Small Force

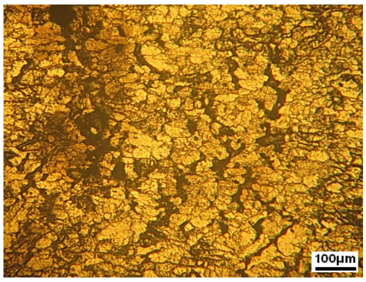
Designation of the Raw Part	Transversal Section		Longitudinal Section	
	Measured	Mean Value	Measured	Mean Value
1.2.3	133-133-133-138-131	133.6	121-121-121-131-123	123.4
1.2.6	115-121-110-106-108	112.0	112-112-110-110-110	110.8
2.2.9	108-117-108-110-115	111.6	127-119-129-131-119	125.0

To test the microstructure and micro hardness, the raw parts were made with melt-on transversal and longitudinal section, sampled from the positions 1.2.3 and 1.2.6 of the damaged pipe, as well as the raw part from the position 2.2.9 of the part of the pipe without damage.

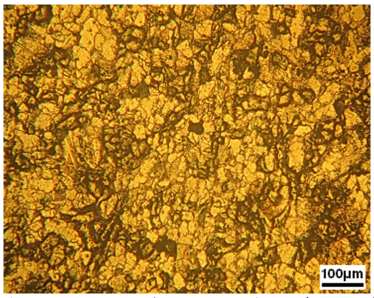
Characteristic micro photographs of the microstructure are shown in Figure 3, and the measured values of the microhardness are given in Table 5.



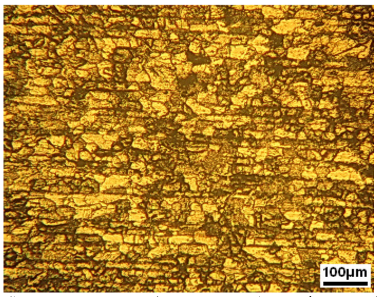
a) Sample 1.2.3 (without etching), longitudinal section, coarse non-metallic inclusions of A3, B1 and D2 type.



b) Sample 1.2.3 (3%/-nital etched), transversal section, propagation of one of the macro cracks inside the pipe material



c) Pipe sample 1.2.6 (3%/-nital etched), transversal section, predominantly ferritic microstructure in the pipe cross section



d) Pipe sample 2.2.9 (3%/-nital etched), longitudinal section, predominantly ferritic, finely stripped microstructure in longitudinal section of the pipe.

Figure 3. Characteristic Micro Photographs of Tested Microstructure

5. MECHANICAL TESTING

5.1 Tensile tests

The results of testing of the specimens at room temperature, +20°C, are shown in Table 6, and that at elevated temperature, +540°C, in Table 7.

5.2 Impact energy tests

The results of impact energy tests at room temperature, +20 °C, conducted with the specimens of both damaged and undamaged parts of the pipe, are shown in Table 8.

Table 6. The Results of Tensile Tests at Room Temperature, +20 °C

Specimen	Mean Value			
	R_e, MPa	R_m, MPa	$A_{5.65}$, %	Z, %
1.2.1.1, 1.2.1.2, 1.2.4.1	218.3	347.0	32.42	68.35
2.2.1.1, 2.2.3.1, 2.2.5.1	231.3	360.3	34.00	71.55

Table 7. The Results of Tensile Tests at Eevated Temperature, +540 °C

Specimen	Mean Value			
	R_e, MPa	R_m, MPa	$A_{5.65}$, %	Z, %
1.2.2.1, 1.2.2.2, 1.2.4.2	127.7	148.7	/	/
2.2.2.1, 2.2.4.1, 2.2.6.1	116.7	139.0	/	/

Table 8. The Results of the Impact Energy Tests of the Damaged Part of the Pipe

Specimen	Orientation	Mean Value, $KV_{2/300}$, J
1.2.5.1, 1.2.5.2, 1.2.5.3	Longitudinal[a]	50.68
1.2.6.1, 1.2.6.2, 1.2.6.3	Transversal[b]	30.08
2.2.7.1, 2.2.7.2, 2.2.8.3	Longitudinal[a]	51.01
2.2.9.1, 2.2.9.2, 2.2.9.3	Transversal[b]	42.51
2.2.11.1, 2.2.11.2, 2.2.11.3	Longitudinal[c]	63.11
2.2.10.1, 2.2.10.2, 2.2.10.3	Transversal[c]	58.21

[a] notch in radial direction; [b] notch in axial direction; [c] notch in the direction of the material thickness.

5.3 Hardness tests

The results of the hardness tests conducted with both damaged and undamaged parts of the pipe are shown in Table 9.

Table 9. The Results of the Measurement of Hardness

Raw Part	Hardness, HBW 5/7500/20"	Mean Value, HBW
1.2.6	117 - 114 - 117	116
2.2.9	114 - 111 - 110	112

6. CONCLUSIONS

Chemical composition and mechanical properties of pipe material for the steam line do not correspond to the stated pipe material of 15128.5 grade according to ČSN standard [1], which suggests that the background and quality of the pipe built-into the steam line are unknown, and therefore inadmissible. Also, the chemical composition of the material does not correspond completely to any steel grade for seamless pipes of non-alloy and alloy steels with properties specified for elevated temperature as defined by standard EN 10216-2 [5].

The chemical composition of the material approximates to the steel grade designated as P265GH, while mechanical properties approximate to the steel grades designated as P195 GH and P235GH, which can be interpreted as a result of the conditions of exploitation, i.e. continuous operation without regular and emergency inspection.

The cause of leakage is the inhomogeneity of the material and a greater number of hours in operation than prescribed, and the result is creep of the base metal, leakage and failure of the steam line.

In order to prevent such phenomena, it is necessary to have a system of preventive maintenance and keep accurate records of all actions on the steam line, as well as to keep records on the quality of the materials built-in at the beginning and during exploitation of the steam line, respecting the terms of regular and emergency inspection prescribed by the Regulations.

It is necessary to estimate the exploitation life of the steam line on the undamaged part of the steam line, based on reliably established quality of the materials built-into steam line, the methods of non-destructive testing (NDT), including endoscopy, in correlation with the technique of risk-based inspection (RBI) [4, 6].

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