Proceedings of the
3rd Youth Symposium on Experimental Solid Mechanics

TESTING OF THE MECHANICAL PROPERTIES FOR 15Mo3 STEEL

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Introduction. In this paper it has been investigated the change of mechanical properties of the low-alloy steel 15Mo3 (according to DIN 17175-79) that has been in service. This material was used for boiler evaporating pipes in thermal power plant "Kostolac B". The boiler is "Sulzer" type, with membrane wall, forced circulation and mixture flow. The aim of the research was to see if there were any significant changes in mechanical properties and to determinate what caused the pipe failure.

Materials and Methods

Material that has been used in research is 15Mo3 steel (A204 Gr. A according to ASTM standard).

Boiler pipes made from this material are delivered in "normalized" condition. With this thermal process (normalization) pipes were heated to the temperatures 910-940 °C. Maximum working temperature for this steel is 475 °C. Main mechanical characteristic at room temperatures are: tensile strength R_m = 440-570 MPa; yield strength $R_{p0,2}$ = 265 MPa, and elongation A = 23 %.

There have been more than 30 specimens taken from different positions in the boiler. The temperatures to which they were exposed are different depending on the position in the boiler. In this paper only ten most representative specimens will be discussed. All the specimens were in service more than 10 years except specimen number 10 which was in service only 3 years.

Testing that has been done included chemical and metallographic analysis, testing of hardness, tensile and toughness testing.

For chemical composition analysis it has been used quantmeter "ARL-3640" (30 x 30 x pipe thickness as a test piece) and for classical method chippings.

Microstructure testing was done on optical microscope "Metalo Plan, Leitz", with test pieces 10 x 10 x pipe thickness.

Determination of hardness was done by Vickers (30 x 30 x pipe thickness as a test piece): time 15 s, temperature 20 °C, force 300 N.

Tensile testing was done according to ASTM standard [1], with "Schenk Trebel RM 100", tensile test machine at the room temperature.

Toughness testing was done through determining resistance on impact test according to force energy determined by instrumented Charpy test. Procedure of testing was according to ESIS standard [2], but test pieces (because of technical problems) had dimension: 5x5 mm with 1mm deep notch in the middle - according to JUS standard [3]. Testing was made at the room temperature (20 °C) with instrumented pendulum "Tecktronic, Schenk Trebel 300 J" (Figure 1).

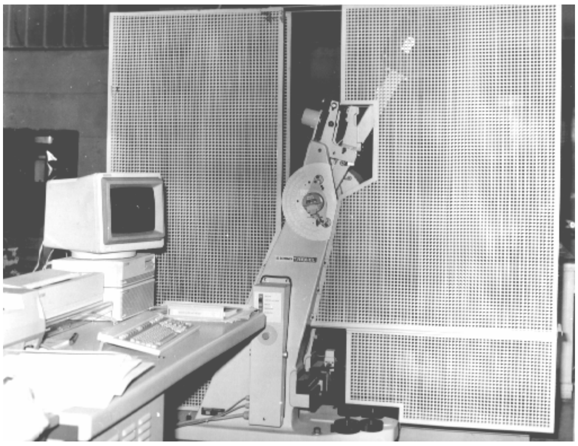

Figure 1

Results

Chemical analysis confirmed that the material was 15Mo3 steel and that composition variation was in the permissive range.

 ISBN-88-901080-8-8-4406

In metallographic analysis, according to the photographs with magnification x 100 and x 500, there was determined the grain size using JUS standard [4], and percentage of pearlite. The results are given in table 1.

Table 1

Specimen label	Grain size	Pearlite percentage
I	6	15-18
II	6	15-18
III	8	12-15
IV	8	15
V	7	20
VI	6	15-18
VII	6	15-18
VIII	6	20
XS	8	25-30
XN	8	12

Metallographic analysis showed normal ferrite-pearlite structure with non-uniformly grain size and there was no sign of degradation caused by creep. On the specimen XS and XN there was structure degradation due to the fact that they were exposed to the highest temperatures. In table 2 there are the results of hardness and tensile testing and corresponding temperatures that specimens were exposed during there service.

Table 2

Specimen label	Temperature [°C]	HV_{30} [MPa]	R_m [MPa]	$R_{p0,2}$ [MPa]	A [%]
I	379	167	326	470	29
II	452	171	327	461	31
III	496	162	425	535	26
IV	528	151	350	438	24
V	571	156	351	468	28
VI	682	145	363	485	29
VII	799	150	366	484	26
VIII	852	184	371	533	29
XS	944	148	281	399	26
XN	944	138	254	399	28

Hardness results are in correlation with percentage of carbon and percentage of pearlite in specimen. Values of tensile testing are in the expected range, except specimen XS and XN where the values are decreased according to the metallographic analysis.
Results of the impact test energy are shown in table 3. Total impact energy W_t was calculated from area under complete force-displacement curve, partial impact energy for crack initiation W_m from area under curve $F = 0$ to $F =$ maximum force. Partial impact energy for crack grow W_g was determinated as difference of W_t and W_m.
Values of total energies show that plasticity is good, which also can be proved by comparing partial energies for crack initiation and crack grow.

Table 3

Specimen label	W_t [J]	W_m [J]	W_g [J]	Diagram type
I	37,2	14,0	23,2	E
II	42,0	18,6	23,4	E
III	35,5	15,6	19,9	F
IV	35,8	14,1	21,7	F
V	32,1	13,2	18,9	F
VI	30,7	14,3	16,4	F
VII	30,4	12,1	18,3	F
VIII	28,1	13,1	15	E
XS	26,3	9,6	16,7	E
XN	24,7	7,4	17,3	F

Partial impact energy for crack grow in all the specimens is bigger then partial impact energy for crack initiation.

Conclusions and discussion

Based on the testing results and analysis of boiler evaporating pipes (including chemical and metallographic analysis, hardness and mechanical properties) material failure with reduced plasticity has been noticed. Since there was no sign of creep the failure is probably related to the overheating caused by the temperature above the operating values in certain period of time.
This could be caused by technical or technological reasons and one of the solutions could be replacing the material with some other that can operate at higher temperatures.

References

[1] E8M-03, *Standard Test Methods for Tension Testing of Metallic Materials [Metric]* [2] ESIS, *Instrumented Charpy-V standard* [3] JUS EN 10045-1:1993, *Mehanička ispitivanja metala - ispitivanje udarom po Šarpiju - Deo 1: Metoda ispitivanja* [4] JUS C.A3.004:1985, *Mikroskopsko određivanje veličine feritnog ili austenitnog zrna čelika*