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SLOW STRAIN RATE TESTING OF STEEL 14MoV6-3

Damir Hodžić, M.Sc.Mech.Eng.
Faculty of Mechanical Engineering
Vilsonovo šetalište 9, Sarajevo
Bosnia and Herzegovina

Ismar Hajro, M.Sc.Mech.Eng.
Faculty of Mechanical Engineering
Vilsonovo šetalište 9, Sarajevo
Bosnia and Herzegovina

ABSTRACT
Slow strain rate test (SSRT) represent a dynamic slowly increasing strain imposed by an external means on uniaxial tension specimen according to ASTM G 129 standard. It is used for relatively rapid screening or comparative evaluation of environmental, processing or metallurgical variables that can affect resistance of material. Testing has been accomplished on low-alloyed boiler steel 14MoV6-3 specimens at elevated temperature 540 °C. Specimens of steel 14MoV6-3 for investigations are taken from the main steamline of Unit 5 Thermal power plant Kakanj. Investigation has included two conditions of the same material 14MoV6-3. The first condition is the material that was not in exploitation at power plant steamline, and the second condition is the material that was in exploitation almost 200.000 working hours at steam temperature 540 °C and pressure 13,5 MPa. As a result of prolonged lifetime of exploited material there is a significant degradation of mechanical properties. In addition to the slow strain rate test, tensile testing at elevated temperature 540 °C with high strain rate and standard strain rate is also performed with the aim to investigate dependence between strain rate and mechanical properties of steel 14MoV6-3. Results of this investigation are given in comparative manner between un-exploited and exploited material.
Keywords: Strain rate, elevated temperature, 14MoV6-3 properties

1. INTRODUCTION
The steel 14MoV6-3 concept goes back to the dawn of creep resistant steels. Experiments with single alloy molybdenum-vanadium steel go back to the time prior to World War II and this steel appears to have stood the test already during the war. The difficult post-war supply situation contributed essentially to the evolution of this low-alloy, but cheap steel of the West German Edelstahl and Roehrenwerke. Creep rupture strength of steel 14MoV6-3 was clearly superior to that of the higher alloyed steel 10CrMoV9-10 which was adopted in West Germany, [1].
When looking back one should not forget that suitable creep resistant steels were in short supply around 1950. This was due to the interrupted material advancement during the war and in the post war period. The steel 14MoV6-3 is the exception among the creep resistant, weldable, ferritic boiler and pipe steels, since it is hardening, thus differing substantially from the performance of the other creep resistant, ferritic steels, [1].
Because of microstructural evolution and degradation of properties of this steel in exploitation the inspection measures on creep damage should be planned and started depending on evaluation of the exhaustion degree. According to the German Codes VGB-R 509L and TRD 508 the start or extended material inspection is required after about 70.000 h for steel 14MoV6-3 and about 100.000 h of exploitation for the other heat-resistant steels, [2].

2. PROPERTIES AND MICROSTRUCTURE OF STEEL 14MoV6-3
Nevertheless to the very long history of low-alloy steel 14MoV6-3 this material is still built in the numerous thermal power plants, particularly in the boilers and its belonging high-temperature

components. Components of power plant boiler are exposed to elevated temperatures, aggressive environment, creep, fatigue, and other damage mechanisms that can cause degradation, deformation or cracking of components. Chemical composition of steel 14MoV6-3 according to normative DIN 17175/79 is presented in Table 1.

Table 1. Chemical composition of steel 14MoV6-3 according to DIN 17175, [3]

Grade	C, %	Si, %	Mn, %	P, %	S, %	Cr, %	Mo, %	V, %
14MoV6-3	0,10-0,18	0,10-0,35	0,40-0,70	Max. 0,035	Max. 0,035	0,30-0,60	0,50-0,70	0,22-0,32

Some of the fundamental mechanical properties of steel 14MoV6-3 that was not in exploitation according to normative DIN 17175/79 are presented in Table 2.

Table 2. Mechanical properties of steel 14MoV6-3 according to DIN 17175, [3]

Mechanical property	Value
Yield strength at room temperature	> 320 MPa
Tensile strength at room temperature	460 – 610 MPa
Elongation at fracture (longitudinal) at room temperature	> 22 %
Impact strength (transverse) at room temperature	> 41J
Yield strength at elevated temperature 500 °C	> 170 MPa

The initial microstructure of the 14MoV6-3 low-alloy steel features the mixture of bainite with ferrite, sometimes with a small amount of pearlite. Occurrences of the significant amount of the M_3C carbides and numerous, very fine MC type ones, are identified in such material. The first stage of the structure changes in exploitation is characteristic of the slight decay of the bainite (pearlite) areas. This is accompanied by coagulation of precipitations in these areas, [4].
The significant decay of the bainite (pearlite) areas due to the long term creep is the next stage of structure changes. On the other hand, on the ferrite grains boundaries precipitations occur forming chains. The final structure image is ferrite with rather homogeneously distributed precipitations inside grains and chains of the significant amount of precipitations on their boundaries, [4].
Microstrutural changes under the influence of temperature, stress and environment in exploitation cause the substantial degradation of mechanical properties.

3. RESULTS OF SLOW STRAIN RATE TESTING OF STEEL 14MoV6-3

Since the parts and machines that are serving the thermal power generation and in other like plants operating at elevated temperatures are subject to damage due to fatigue as well as to creep because of the frequent start-and-stops and changes in the working conditions, precise assessment of the damage incurred in them is a matter of special importance in designing and maintaining such a plant, [5].
Slow strain rate test (SSRT) represent a dynamic slowly increasing strain imposed by an external means on uniaxial tension specimen according to ASTM G 129 standard. It is used for relatively rapid screening or comparative evaluation of environmental, processing or metallurgical variables that can affect resistance of material, [6].
Slow strain rate testing has been accomplished on low-alloyed boiler steel 14MoV6-3 specimens at elevated temperature 540 °C. Specimens of steel 14MoV6-3 for investigations are taken from the main steamline of Unit 5 Thermal power plant Kakanj, Bosnia and Herzegovina. Investigation has included two conditions of the same material 14MoV6-3.
The first condition is the material that was not in exploitation at power plant steamline, and the second condition is the material that was in exploitation almost 200.000 working hours at steam temperature 540 °C and pressure 13,5 MPa.
Testing was done for two different slow strain rates (0,0001 mm/s and 0,000254 mm/s) with tensile testing machine ZWICK ROELL at IWS Institute TU Graz, Austria. Software for data acquisition was testXpert x2.02.0 ZWICK/ROELL. Number of specimens for testing was one per strain rate and

specimens with round cross sections for elevated temperature tensile testing were used. Figures 1 and 2 shows equipment used for slow strain rate testing.

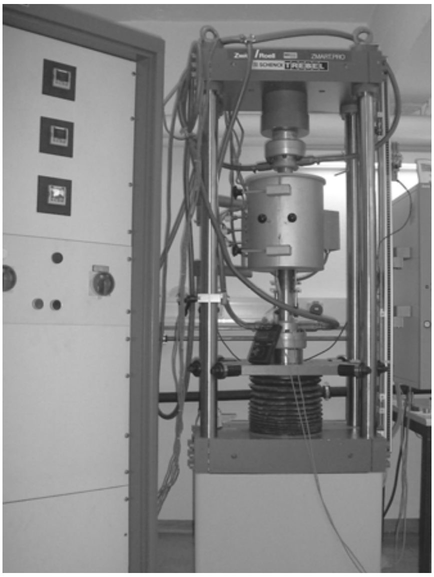

Figure 1. Testing machine

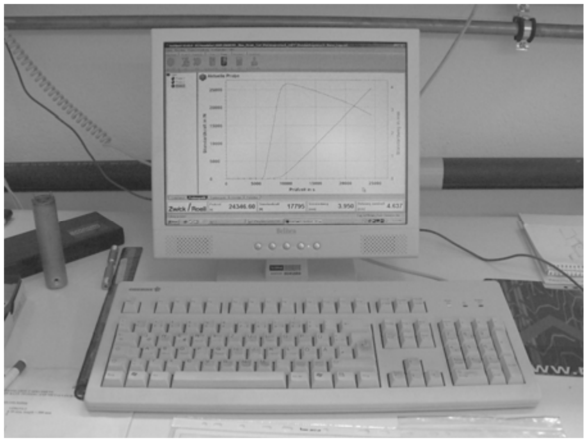

Figure 2. Data aquisition

Results of slow strain rate testing of exploited and un-exploited steel 14MoV6-3 at elevated temperature 540 °C are presented in Tables 3 and 4.

Table 3. Results of slow strain rate testing of un-exploited steel 14MoV6-3

Specimen	**Strain rate, *mm/s***	**Max. load, *kN***	**Time to failure, *h***	**Tensile strength, *MPa***	**Elongation to fracture, *%***
N-E1	0,000254	18,895	8,88	377,71	38,30
N-E2	0,0001	18,846	23,25	374,95	37,45

Table 4. Results of slow strain rate testing of exploited steel 14MoV6-3

Specimen	**Strain rate, *mm/s***	**Max. load, *kN***	**Time to failure, *h***	**Tensile strength, *MPa***	**Elongation to fracture, *%***
E1	0,000254	11,299	10,41	224,79	46,33
E2	0,0001	10,699	26,73	212,86	47,00

In addition to the slow strain rate test, tensile testing at elevated temperature 540 °C with high strain rate 1 mm/s and standard strain rate 5 mm/min (0,083 mm/s) for tensile testing is also performed with the aim to investigate dependence between strain rate and mechanical properties (tensile strength) of steel 14MoV6-3. Number of testing specimens was one specimen per strain rate and testing was accomplished with the same equipment for slow strain rate test at elevated temperature 540 °C.
Results of this investigation are given in comparative manner between un-exploited and exploited steel 14MoV6-3, as shown in Figure 3.

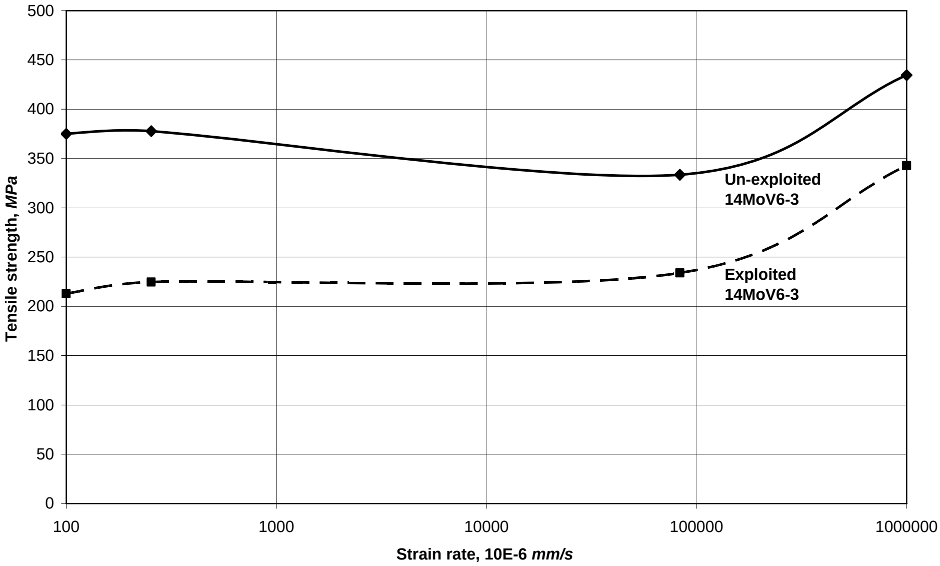

Figure 3. Dependence between strain rate and tensile strength at elevated temperature 540 °C for un-exploited and exploited steel 14MoV6-3

4. FINAL REMARKS

Where possible, the application of the slow strain rate test data and data derived from its use should be used in combination with service experience or long term data, or both, obtained through literature sources or additional testing using other testing techniques.

Considering the results of slow strain rate test of steel 14MoV6-3 presented in Tables 3 and 4, as a result of prolonged lifetime of exploited material there is a significant degradation of mechanical properties. Through the testing with different strain rates at elevated temperature 540 °C there is obviously significant decrease of tensile strength and implicitly other strength properties of exploited steel 14MoV6-3 comparing with un-exploited 14MoV6-3. It should be noticed that with decreasing of strain rate there is also slightly greater decrease of tensile strength of exploited material comparing with un-exploited. Implicitly, it means that it could be expected significant decrease of time dependant strength properties like creep rupture strength, but it should be proved by creep testing.

5. REFERENCES

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