Journal of Trends in the Development of Machinery and Associated Technology
Vol. 17, No. 1, 2013, ISSN 2303-4009 (online), p.p. 53-56

INFLUENCE OF DIFFERENT MECHANICAL PROPERTIES ON RESIDUAL LIFE ESTIMATION

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ABSTRACT
Under exploitation conditions in service microstructure and mechanical properties of metallic materials degrade causing sometimes significant reduction of some particular components life. Microstructure evolution through components material service has different influence on degradation of different mechanical properties. In this paper are presented degradation levels of different mechanical properties such as hardness, tensile strength, yield strength and impact toughness of thermal power plant steamline material 14MoV6-3 after notable prolonged exploitation in service. All of this mechanical properties are presented in comparative manner with aim to emphasize significance of particular mechanical properties investigations, especially for the purpose of making decision for the residual component life estimation.
Keywords: Mechanical properties, Residual life, Steel 14MoV6-3

1. PREFACE
Reliability and safety of thermal power plant components are issues that have become much more important in recent years, so the assessment of damage and of the risk associated with failure have become increasingly important. Records of operating conditions and preventive maintenance for a component that has failed, and for the system as a whole, are relatively good sources of background information. In the absence of documented plant history data the validity of accuracy of remanent life assessment must suffer. If the remaining life determined in calculation and inspection is too short or has an unacceptable level or uncertainty in relation to operational targets, then the more precise evaluation should be implemented. In that case, information requirements include component surveillance and sampling followed by post-exposure tests.
Direct postservice evaluation represents an improvement over history-based methods, because no assumptions regarding material properties and past history are made. Unfortunately, direct examinations are expensive and time consuming.
In order to investigate decrease of mechanical properties of material, low-alloyed steel 14MoV6-3 exposed 194.207 hours of exploitation, has been compared with same, but virgin material. The low-alloyed steel was chosen for this investigation, because it is widely used for steamlines in power plants in Bosnia and Herzegovina, and also because it has been used for long service period (from 1968), so that significant decrease of structure and properties can be expected. Investigated material is taken from the Unit 5 main steamline (ø245×28mm) that operated at temperature 540 °C and pressure 13,5MPa, in thermal power plant TE Kakanj, Bosnia and Herzegovina. Sample of steamline exploited

material 14MoV6-3 was cut because of residual life estimation. Virgin material was also cut from the steamline material 14MoV6-3 (ø245×28mm).

2. HARDNESS TEST RESULTS

In order to investigate decrease of hardness value of exploited steamline material, hardness test was accomplished at room temperature. This was done in laboratory by testing and comparison of hardness values of virgin material and exploited material 14MoV6-3. For hardness test 1 specimen per material condition (virgin and exploited) was used and method was Brinell Hardness test (HB30). Hardness test was done on outer surface, 1.5 mm under the outer surface, and at longitudinal and transversal cross section of steamline pipe. According to European normative EN 10216-2:2002, [1], material 14MoV6-3 is delivering as seamless steel tubes for elevated temperatures with acceptable value of hardness in range of 145 – 190 HB30 at room temperature. Acceptable hardness value at elevated temperatures is not defined by this normative. Results of measured hardness values (HB30) for virgin and exploited steamline material 14MoV6-3 are presented in Figure 1.

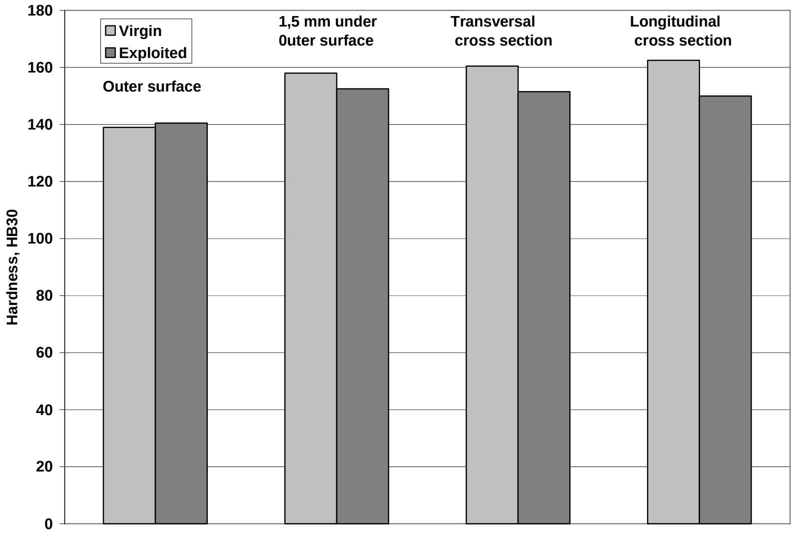

Figure 1. Results of measured hardness values for virgin and exploited material 14MoV6-3, [2] [3]

3. YIELD AND TENSILE STRENGTH TEST

The strength properties can be used also as an indicator for the state of the steel in its life cycle. In order to investigate decrease of strength values of exploited steamline material, tensile test was accomplished at room temperature and at elevated service temperature 540 °C. This was done in laboratory by testing and comparison of strength values (yield and tensile strength) of virgin material and exploited material 14MoV6-3. For tensile test 3 specimens per material condition (virgin and exploited) and per temperature (20 °C and 540 °C) were used. According to European normative EN 10216-2:2002, [1], and standard DIN 17175/79, [4], for material 14MoV6-3 there are acceptable values of yield and tensile strength at room temperature, but only yield strength values for elevated temperatures. Table 1. and Table 2. show acceptable strength values.

Table 1. Strength properties of material 14MoV6-3 at room temperature, [1] [4]

Standard	**Yield strength, (MPa)**	**Tensile strength, (MPa)**
DIN 17175	≥ 320	460-610
DIN EN 10216-2	≥ 345	490-640

Table 2. Strength properties of material 14MoV6-3 at elevated temperatures, [1] [4]

Standard	**Yield strength, (MPa)**		
	450 °C	**500 °C**	**550 °C**
DIN 17175	≥ 185	≥ 170	---
DIN EN 10216-2	≥ 203	≥ 200	≥ 197

Results of tensile test for virgin and exploited steamline material 14MoV6-3 are presented in Figure 2.

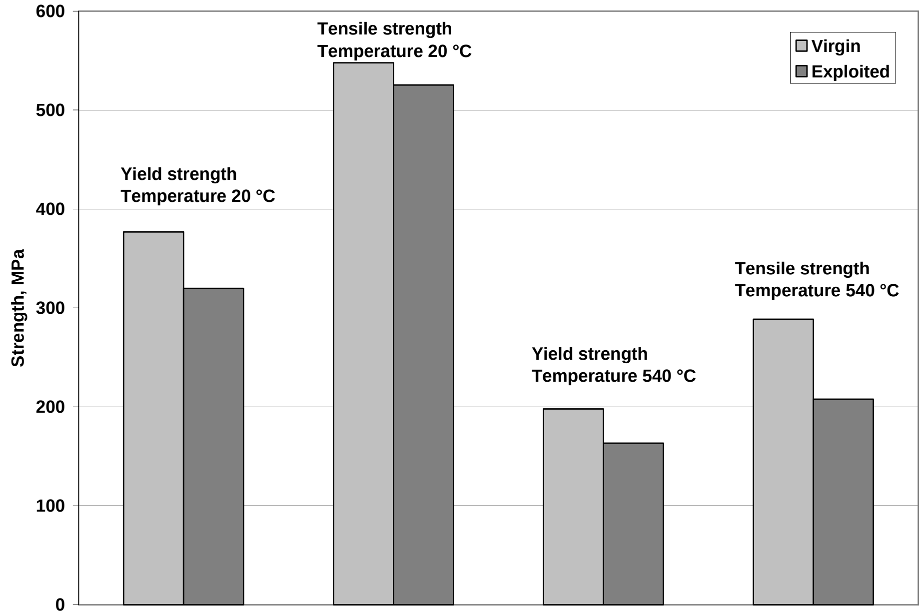

Figure 2. Results of tensile test for virgin and exploited material 14MoV6-3, [2]

4. IMPACT TOUGHNESS TEST

In order to investigate decrease of impact toughness of exploited steamline material 14MoV6-3, following temperatures were selected for impact testing: 20 °C, 150 °C, 400 °C and 540 °C (service temperature). This was done by testing and comparison of impact toughness values of virgin material and exploited material 14MoV6-3. For every testing temperature 3 Charpy V-notch specimens were used. Results of average (3 specimens) impact toughness values (KV) per testing temperature for virgin and exploited material 14MoV6-3 are presented in Figure 3.

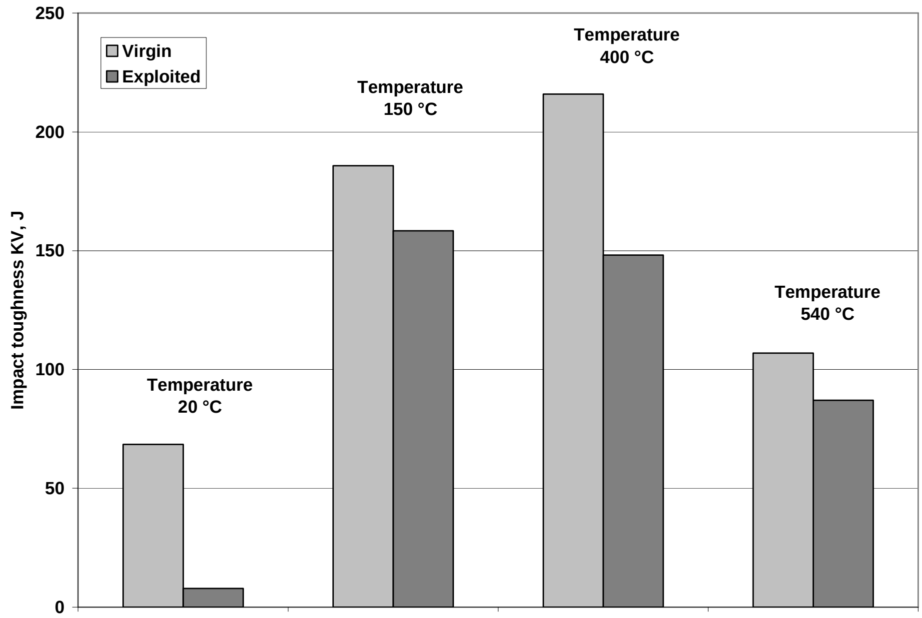

Figure 3. Results of impact toughness test for virgin and exploited material 14MoV6-3, [2] [5]

According to normative DIN 17175/79, [4], material 14MoV6-3 is delivering as seamless steel tubes for elevated temperatures with minimum impact toughness 41 J (transverse specimens) and 55 J (longitudinal specimens) at room temperature. Minimum impact toughness at elevated temperatures is not defined by this normative.

5. FINAL REMARKS

Boilers and other types of steam power plant equipment are subjected to a wide variety of failures involving one or more of several mechanisms. Most steam-generator failures occur in pressurized components, that is, the tubing, piping, and pressure vessels that constitute the steam-generating portion of system, [6]. Progressive damage of high-temperature components under operating conditions leads to exhaustion of life, thus leading to failure. Damage may be defined as a "progressive and cumulative change acting to degrade the structural performance of the load-bearing component or components that make up the plant". Life may be defined as the "period during which a component can perform its intended function safely, reliably, and economically", [7]. According to previous investigations of this material with similar service conditions, that are published in scientific journals, the initial microstructure of the 14MoV6-3 low-alloyed steel features the mixture of bainite with ferrite, sometimes with a small amount of pearlite. The final structure image after prolonged exploitation is ferrite with rather homogeneously distributed precipitations inside grains and chains of the significant amount of precipitations on their boundaries, [8].

Microstructure changes under the influence of temperature, stress and environment in exploitation cause the substantial degradation of mechanical properties. Considering presented results of different tests it is obvious that all investigated properties are degradated but with different level.

Hardness, though apparently simple in concept, is a property that represents an effect of complex elastic and plastic stress fields set up in the material being tested, [9]. The hardness can be used only as an indicator for the state of the steel in its life cycle. All creep resistant power plant steels are severely tempered before they enter service and therefore beyond the state where secondary hardening is expected and the hardness can, during service, be expected to decrease monotonically, [10]. Although hardness measurement in plant is commonly applied technique during maintenance inspection (especially in combination with replica) the most of the published studies are based on laboratory measurement made on test specimens with standard hardness measurement techniques, [11]. Long-term operation of thermal power plant main steamline material at elevated temperature causes decrease of strength, greater in the case of yield strength than in the case of tensile strength, but also significant decrease of impact toughness especially at room temperature. Hardness and impact toughness tests cannot be used for the final assessment of the further steamline safe service time and it is not quite useful for the residual life assessment and for determining of the material exhaustion extent, but obviously it should be included together with the other diagnostic methods as an important indicators.

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