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Mechanical behaviour of material of thermal power plant steam superheater collector after exploitation

O. Yasniy [a,*], T. Vuherer [b,1], V. Yasniy [a], A. Sobchak [a], A. Sorochak [a]

[a] Ternopil Ivan Pul'uj National Technical University, Faculty of Computer Information Systems and Program Engineering, Ruska Street 56, Ternopil 46001, Ukraine
[b] University of Maribor, Faculty of Mechanical Engineering, Smetanova Street 17, Maribor 2000, Slovenia

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ABSTRACT

The article deals with the comprehensive research of temperature influence upon fracture energy of operational 12Cr1MoV steel of steam superheater collector of TP-100 type boiler. The authors found out that heating from 20 °C to 200 °C results in an increase of Charpy toughness and eventual reaching of plateau. There were also spotted the main dependencies of changes of steel microhardness along the thickness of collector considering on the distance from the hole.

1. Introduction

The prevention of sudden failure of pipelines and collectors of steam superheaters of thermal power plants (TPPs) is an important task in engineering [1–4]. Many TPP have already exceeded their designed life expectancy. So the question is: how long can the equipment of power plants operate? To answer this question one has to obtain a number of experimental data, material properties, including ultimate tensile strength, yield strength, and their changes in time, as well as to choose the appropriate fracture criteria and testing methodology. It is important to study the parameters that are sensitive to degradation of the material and can be determined by destructive or non-destructive methods.

The TPP collectors of superheaters are operated at temperatures between 400 °C and 500 °C in the medium of water under the pressure 15.5 MPa. Aggregate action of these factors, as well as corrosion environment and slow deformation, results in a decrease of collector steel plasticity and the degradation of its mechanical properties.

Long-term maintenance of steam superheaters collectors causes the structural and phase changes in 12Cr1MoV steel: pearlite colonies are likely to disintegrate; carbides become of sphere shape; the number of carbides increases, and pores are formed at the grain boundaries [5,6]. The stress corrosion is the main reason for initiation and propagation of the cracks on the inner surface of the collector along the grain boundaries. These boundaries are weakened by pores and by precipitation of carbides. Internal carbon depletion under intense irreversible hydrogen embrittlement and loss of intergranular strength affect significantly on the degradation of 12Cr1MoV steel. The goal of the work is to study the influence of operating time upon hardness, microhardness and Charpy toughness of 12Cr1MoV steel.

* Corresponding author. Tel.: +380 352 526613; fax: +380 352 254983.
E-mail addresses: oleh.yasniy@gmail.com (O. Yasniy), tomaz.vuherer@uni-mb.si (T. Vuherer).
[1] Tel.: +386 2220 7677; fax: +386 2220 7990.

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2. Research methods

The collector of steam superheater of TP-100 type boiler was made of 12Cr1MoV steel (GOST 5520-79). The material of TP-100 type boiler steam *superheater* collector, which was dismounted after 178,440 operation hours, was studied. The Charpy specimens that were cut out from the area of collector pipe with outer diameter 325 mm and wall thickness of 50 mm are presented in Fig. 1a. To examine the distribution of Charpy toughness in the radial direction *R* on the thickness, the specimens were taken from the outer, middle and inner wall sections of collector. In all cases, the specimens were cut out in plane being perpendicular to the axis *L* of collector pipe. The templates were cut from the perforated collector segment for the analysis of hardness and microhardness (Fig. 1b). In the perforated segment of the collector there are three rows of 27 holes with a diameter of 22 mm with welded connections for the nozzles with a step of 80 mm in axial direction and 57.6 mm in the circumferential direction (development of outer surface). The part of the collector made of 12Cr1MoV steel with holes for nozzles is presented in Fig. 1c and d shows the thin section of collector material that was used for microstructural analysis.

The Charpy toughness was determined by testing of specimens (10 × 10 × 55 mm) with ISO V-shaped notch and radius 0.25 ± 0.025 mm on Amsler RKP-300 instrumented impact tester with nominal energy 300 J according to ASTM E23-07ae1 [7] and ASTM E2298-09 [8]. Three series of tests with six specimens in each series were carried out at 20 °C, 200 °C and 300 °C with recording of the "force–time" data. Based on the obtained diagrams, the initiation energy E_i, energy of crack propagation E_p, fracture energy *E* and Charpy toughness *KCV* were determined.

The Charpy toughness was evaluated by the formula:

$$KCV = A/F \tag{1}$$

where *A* is a full work of specimen fracture; *F* is a cross-sectional area of the specimen in the place of notch.

Meanwhile the test "VUHI-CHARPY" software controls the Amsler RKP-300 Charpy pendulum and records the data of force and energy from the sensors during the impact that enables determining the force–time diagram.

The initial velocity of the impact v_0 can be calculated from the pendulum mass *m*, length and starting angle of the pendulum. The dependence $v(t)$ "velocity–time" can be determined by equation [7,9,10]:

$$v(t) = v_0 - \frac{1}{m}\int_{t_0}^{t} P(\tau)d\tau. \tag{2}$$

After that the dependence of pendulum displacement from the time $s(t)$ is obtained:

$$s(t) = \int_{t_0}^{t} v(\tau)d\tau. \tag{3}$$

Finally, the diagram "force–displacement" can be constructed. The area below the curve on the diagram is numerically equal to the fracture energy of the Charpy test. This energy can be calculated with the following equation:

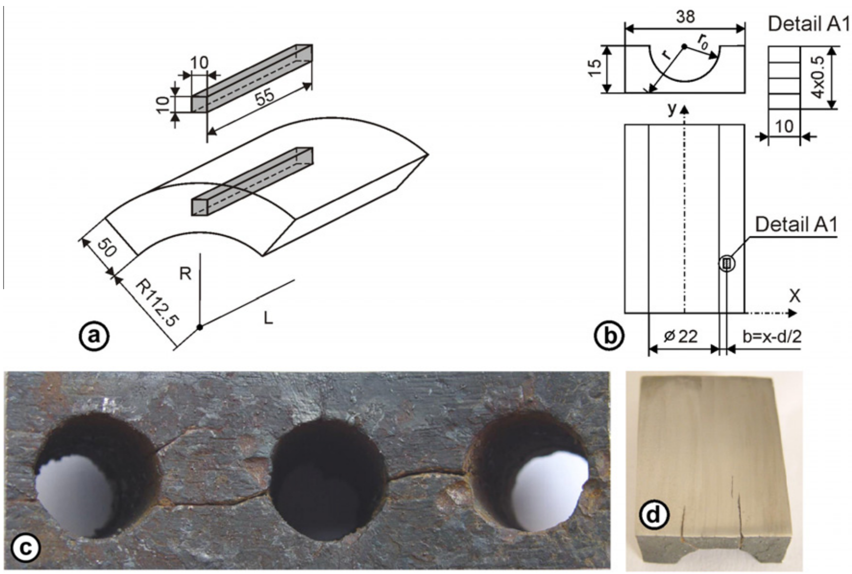

Fig. 1. Cutting scheme of specimens taken from perforated area of collector: (a) for testing on Charpy toughness; (b) for measurement of hardness and microhardness; (c) part of the 12Cr1MoV steel collector with holes for nozzles, (d) thin section for microstructural studies.