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CORROSION OF AIR PREHEATER TUBES OF OIL SHALE CFB BOILER. PART II. LABORATORY INVESTIGATION OF TEMPERATURE IMPACT

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The objective of the work was to investigate temperature impact on corrosion of air-preheater tubes of oil shale CFB boilers. With this objective in view, laboratory corrosion tests of carbon steel St 33 used for manufacturing of air-preheater tubes have been carried out in the atmosphere of air and water steam in the presence of oil shale ash in the temperature range of 75–110 °C. The results have shown that corrosion rate of the metal was maximal at the temperature of 90 °C and minimal at the temperature of 110 °C, which could be recommended as the operation temperature of the metal of air-preheater tubes of oil shale CFB boilers with respect to safe operation of tubes.

Introduction

As generally known, metal temperature of the air-preheater tubes depends on both temperatures: of the air flowing outside and flue gases flowing inside the tubes. Consequently the lower the temperature of the air entering the air-preheater, the lower the temperature of the wall of air-preheater tubes, that in turn increases the intensity of flue gas cooling. Decrease of flue gas temperature increases the efficiency of the boiler. Generally low-temperature corrosion starts at the dew point of sulphuric acid. It is well known by now that CFB boilers utilizing Estonian oil shale bind most of sulphur compounds during the combustion process, and the concentration of SO_2 and SO_3 in flue gases is very low. In this case low-temperature corrosion of air-preheater tubes is apparently caused by chlorine compounds. Corrosion rate of the tubes is dependent on the temperature of the tube wall. However, data about the effect of the tube wall temperature on corrosion of the air-preheater tubes of oil shale CFB boilers are lacking. Therefore the objective

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of the given work was to perform laboratory corrosion tests at different temperatures of the metal in order to find out the optimal temperature of tube walls for safe operation of the air preheater.

Experimental

Flat specimens for laboratory testing of corrosion (Fig. 1) had been made from carbon steel St 33 which is used for manufacturing of air-preheater tubes. The tests were carried out in the atmosphere of air and water steam in the presence of oil shale ash, taken from the air-preheater bin of the CFB boiler. 167-h and 500-h tests were conducted at 75, 90, 100 and 110 °C. The starting temperature 75 °C was chosen as the dew-point temperature of flue gases of PF oil shale boiler according to investigation [1].

The tests at 75, 90 and 100 °C were performed in an exsiccator placed into an electrically heated oven (Fig. 2a). The exsiccator was partially filled with water. The specimen and oil shale ash were placed into a special glass capsule, the bottom of which was a filter that let the steam pass through the ash layer (Fig. 2b, 2c). The capsule was set on the perforated shelf of the exsiccator above the level of the water. Thus, the steam flowed to the specimen immersed into the oil shale ash in the capsule. The test temperature in the oven was maintained automatically with the accuracy of ±2 °C.

In the case of testing temperature of 110 °C the test was performed in a container of the diameter of 60 mm, into which the capsule with testing specimen immersed into the oil shale ash had been placed. The container was connected to the steam boiler (steam sterilizer ГК-100-3М) that allowed maintaining the steam pressure in the range of 1.0–2.2 bars (Fig. 3a). During the test the steam pressure was initially set at 1.5 bars that corresponded to the saturated steam temperature of 110.8 °C.

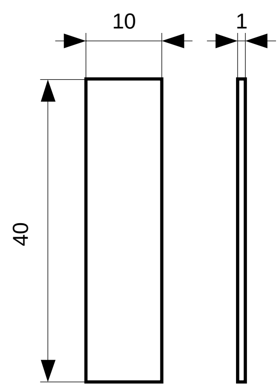

Fig. 1. Specimen (dimensions are in mm).

(a)

(b) (c)

Fig. 2. (a) – exsiccator placed into the oven; (b), (c) – glass capsule with the specimen and oil shale ash before and after corrosion testing.

It was found that in the container oil shale ash in the presence of saturated steam had firmly hardened by 24 hours of testing. At the next stage, in order to avoid hardening of the ash, the operating steam pressure in the boiler was set at 1.0 bar. Steam was heated to the temperature of 110 °C by means of an additional electrically heated pipe which connected the boiler and the container with the specimen (Fig. 3b). In this case the superheated steam passed through the ash containing the specimen, and the ash did not harden firmly. It has allowed to maintain testing temperature of the steam at the level of 110 ± 2 °C and to carry out the test successfully without ash hardening.

(a) (b)

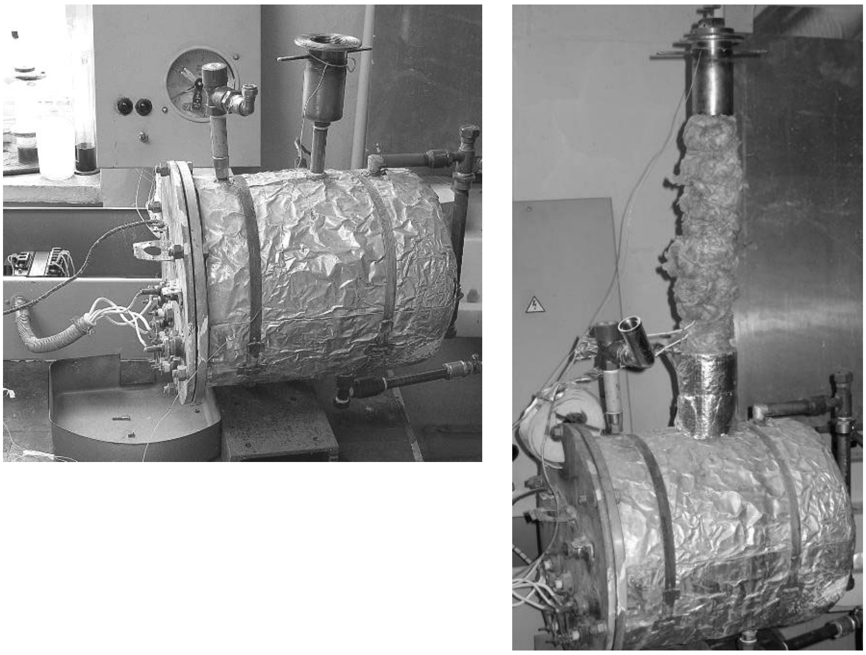

Fig. 3. Experimental unit for testing corrosion rate at 110 °C without (a) and with (b) electrical heating.

Corrosion depth of the specimens was determined on the basis of mass change (Δm, g) by weighing the clean degreased specimens before and after testing. Prior to weighing of the tested specimen, corrosion products and oxide scale were completely removed from the surface of the specimen in the 10% solution of ammonium citrate. The specimens were weighed by means of balances with the accuracy of 0.0001 g. On the basis of the decrease in specimen mass specific material loss (q, g/cm^2) was determined. Finally, according to [2], corrosion depth (ΔS, mm) of the specimens was calculated using the following equation: $\Delta S = 1.28q$.

Results and conclusions

The results of laboratory corrosion tests are presented in Table 1 and Fig. 4. For comparison of testing results a well-known factor has been used, namely corrosion rate V, mm/year. As one can see, the maximum corrosion rate is at the temperature of 90 °C. The subsequent increase in the testing temperature leads to the decrease of corrosion rate, and at the temperature of 110 °C the tested specimens practically do not suffer from corrosion. The specimens taken after corrosion testing at the temperatures of 75 and 110 °C are presented in Fig. 5.

Table 1. **Results of laboratory corrosion tests of steel St 33**

t, °C	*τ*, h	Δ*m*, g	*q*, g/cm^2	Δ*S*, mm	*V*, mm/year
75	167	0.14	0.016	0.020	1.059
75	167	0.14	0.016	0.021	1.087
75	167	0.21	0.023	0.030	1.550
75	167	0.25	0.028	0.035	1.847
75	500	0.63	0.074	0.094	1.653
75	500	0.55	0.066	0.084	1.472
90	167	0.477	0.053	0.068	3.582
90	167	0.500	0.055	0.070	3.661
90	500	0.709	0.079	0.101	1.777
90	500	0.663	0.073	0.094	1.643
100	167	0.033	0.004	0.005	0.248
100	167	0.032	0.004	0.005	0.237
100	500	0.101	0.011	0.015	0.255
100	500	0.088	0.010	0.013	0.224
110	500	0.000	0.000	0.000	0.000
110	500	0.001	0.000	0.000	0.002

t – testing temperature, °C
τ – test duration, h
Δ*m* – change of specimen mass, g
q – change of specimen mass per unit of area, g/cm^2
Δ*S* – corrosion depth, mm
V – corrosion rate, mm/year

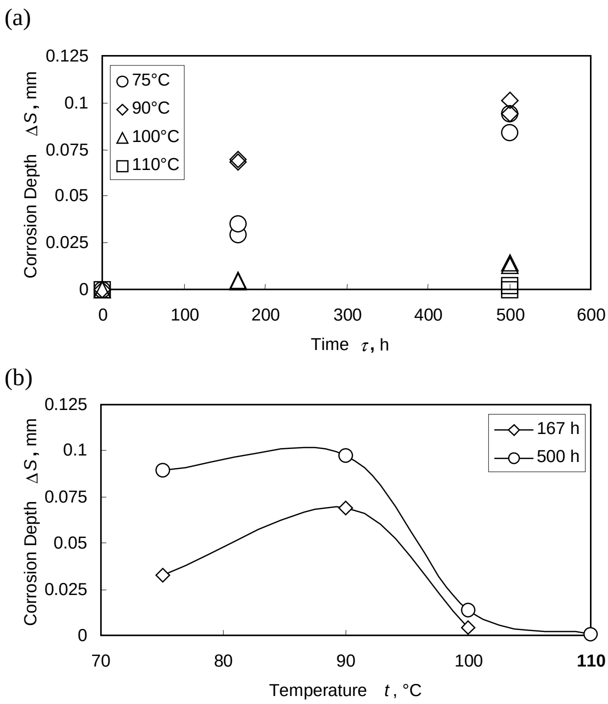

Fig. 4. Corrosion depth of specimens made from St 33 depending on time (a) and temperature (b).

(a)
(b)

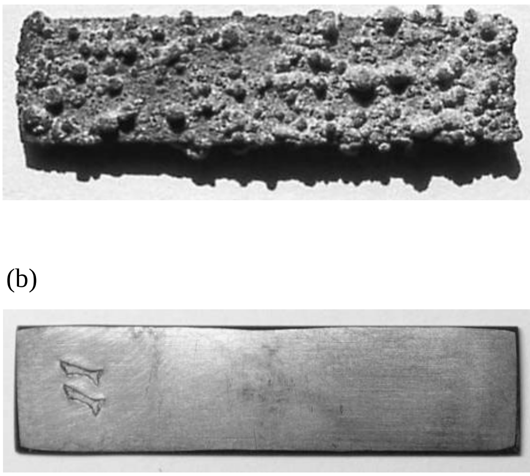

Fig. 5. Specimens after corrosion testing during 500 hours at 90 °C (a) and 110 °C (b).

Thus, the results of the laboratory corrosion testing of carbon steel St 33 at different temperatures allow to recommend the metal temperature of the tubes located in the area of the air inlet into the air-preheater of the oil shale CFB boilers to be held at the level of 105–110 °C. However, it should be noted that in the conducted experiments oil shale ash from the air-preheater bin of the CFB boiler was used, while the ash deposits on the surface of the air-preheater tubes could consist of finer particles. Such deposits are able to bind chlorine from flue gases and hence to cause more intensive corrosion of the tubes than can the coarser grained ash from the air-preheater bin [3].

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