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Date: 22.12.2011
Subscriber: Finnish Recovery Boiler Committee

FURNACE TUBE TEST PROBE

The aim of this test was to expose selected materials to recovery boiler furnace conditions for about 2720 hours, i.e. the same time as used in previous test, so that the average material temperatures on furnace side surface is 440°C ± 10°C. Materials tested were 3R12 (304L), Sanicro28, Sanicro38 and HR11N.

The test was started by installing the test probe in place on 26nd of July 2011. Set value for system pressure was set at 9,4 bar(a). The test began when pressure exceeded 8,0 bar(a) at 8:36 am. The saturation temperature of heat transfer oil exceeded then 370°C according to thermocouple readings (and was about 20°C more than water saturation temperature at 170 bar pressure).

The test was completed on 19th of December 2011 at 10:30 am when the probe had been exposed to recovery boiler furnace conditions for 2630 hours, i.e. close to the target time.

Instrumentation of the test device

The test probe was equipped with four thermocouples, two of which installed vertically and horizontally in the middle of the top (3R12) and the lowest (HR11N) test pieces. Other two thermocouples were installed inside the tip, one measuring the cooling oil temperature and the other one inside surface temperature. The set value for system pressure was selected on the basis of the thermocouple readings and the data from previous tests. The pressure was adjusted with a cooling fan regulated by PI controller.

The probe was also equipped with two electric heating elements to make sure that the system pressure would not drop too low when the tip of the probe is sprayed by black liquor (the probe was installed in an empty liquor gun opening, i.e. close to operating liquor guns). The electric heating elements were automatically turned on/off when temperature of the test device dropped below/increased above the set point. The set point was selected so that the system pressure would remain above 3 bar(a) (with cooling oil saturation temperature more than 315°C) all the time the probe is installed.

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Inner side surface temperature, cooling oil temperature and system pressure during the test

In figure 1 are shown the temperature on the inner side surface, cooling oil saturation temperature and system pressure during the test.

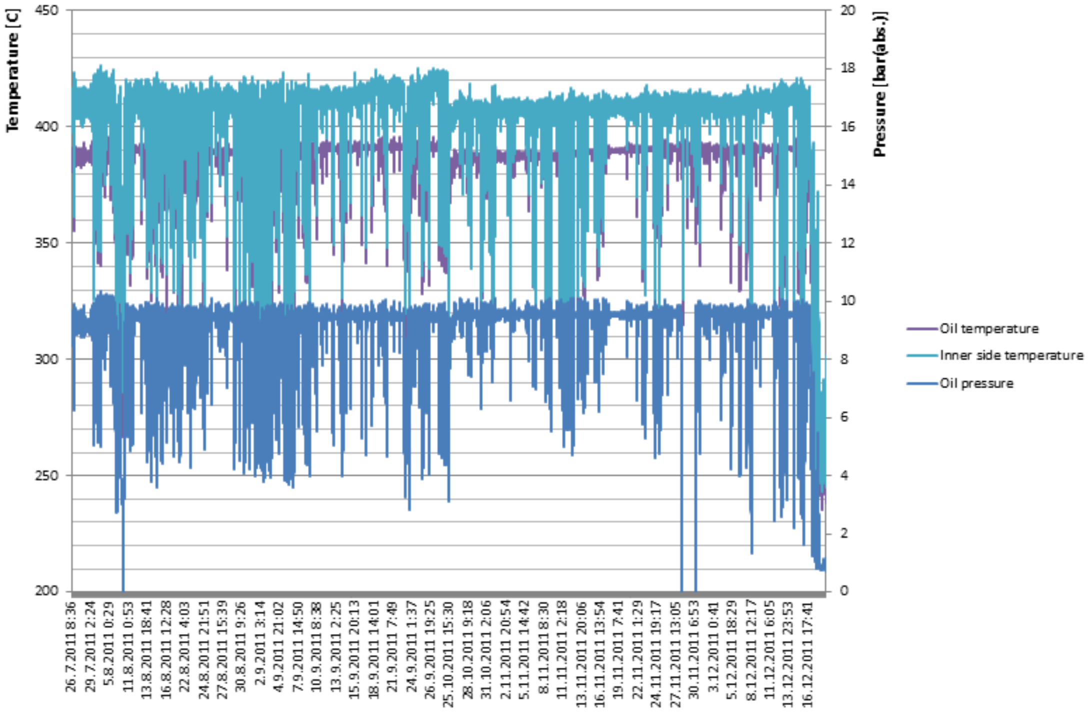

Figure 1. Inner side surface temperature, cooling oil saturation temperature and system pressure during the test.

During the test there was found small leakages in the test probe cooling oil system and the probe had to be drawn out of the liquor gun opening two times and cooled down for repairing the leakages.

During the test period the recovery boiler in question was also shut down for annual outage for about 30 days. After the outage the cooling oil was replaced and the cooling oil system was rinsed with a solvent to clean the system. That than be seen in a slight drop in probe inner side temperature roughly in the middle of the test period.

During the whole 2630 hour test period the system pressure stayed above 8 bar(a) 2157 hours (2154 hours in previous test).

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Material temperatures

The two thermocouples inside the test pieces broke down almost immediately after installing the probe into liquor gun opening. Due to this the calculated heat fluxes from the previous test will be referred in estimating the temperatures on test pieces on furnace side surfaces. The probe geometry and operation were the same in both tests.

In previous test the average heat flux across the top test piece was calculated to be 142 kW/m^2 and 173 kW/m^2 across the lowest test piece. Average inner side temperature was now 410,8 °C, which is close to what it was in previous test 411,6 °C. Heat fluxes across the test pieces can now be estimated to be roughly the same as in previous test and can be used in estimating the test piece surface temperatures.

Heat transfer coefficient for 3R12 material (top test piece) at 400 °C is 22 W/m°C, 45,3 W/m°C for carbon steel at 400 °C and cladding thicknesses 1,65 mm for 3R12 material and 4,88 mm for carbon steel. Heat transfer coefficient for HR11N material (lowest test piece) 400 °C is 18,5 W/m°C and material thickness 3,64 mm.

Now the estimates of material temperatures on probe furnace side surface can be calculated by using above mentioned material properties, measured inner side temperature and estimated average heat fluxes obtained from the previous test. In figure 2 are shown the temperature distributions on upper and lower test pieces during the test.

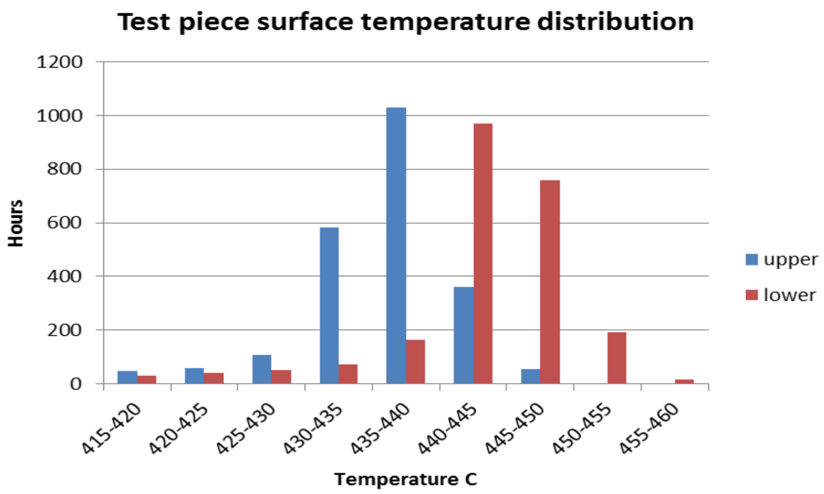

Figure 2. Temperature distribution on upper and lower test piece on furnace side surfaces during the test.

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Summary

Test material average temperatures were estimated to be close to what they were in previous test according to probe inner side temperature measurements (410,8 °C vs. 411,6 °C). The estimate of the average temperature on the surface of the top test piece (3R12) was now 437°C and 445°C on the surface of the lowest test piece (HR11N). The total exposure time was 2630 hours of which the pressure stayed above 8 bar(a) 2157 hours, i.e. 82 % of the time.

The temperatures in other two test pieces were not measured, but there is no reason to believe that they would have been markedly different from those of the upper test piece.

As the estimated surface temperatures in all test pieces were reasonable close to the target value of 440 ± 10°C for a significant portion of the test duration and there were no uncontrolled excursion of material temperatures, the test was carried out successfully.