Subscriber Soodakattilayhdistys 6.7.2010

FURNACE TUBE TEST PROBE

The aim of this test was to expose selected materials to recovery boiler furnace conditions for 1000 hours so that the average material temperature (on furnace side surfaces) is 440°C ± 10°C. Materials tested in this test were 3R12 (304L), San 67, welded 25 % Cr and HR11N.

The test was started by installing the test probe in place on 10th of May at 2:00 pm. Set value for system pressure was set at 7,3 bar(a) for a day and then increased the next day to 8,8 bar(a). The test began when pressure exceeded the set value 7,3 bar(a) on 10th of May 2010 at 6:13 pm. The saturation temperature of heat transfer oil exceeded then 370°C (and was about 20°C more than water saturation temperature at 170 bar pressure).

The test was completed on 23th of June 2010 at 12:11 pm when the probe had been exposed to boiler furnace conditions for 1023 hours. That doesn't include the time needed for repairs, as there was a small leak in the probe during the test.

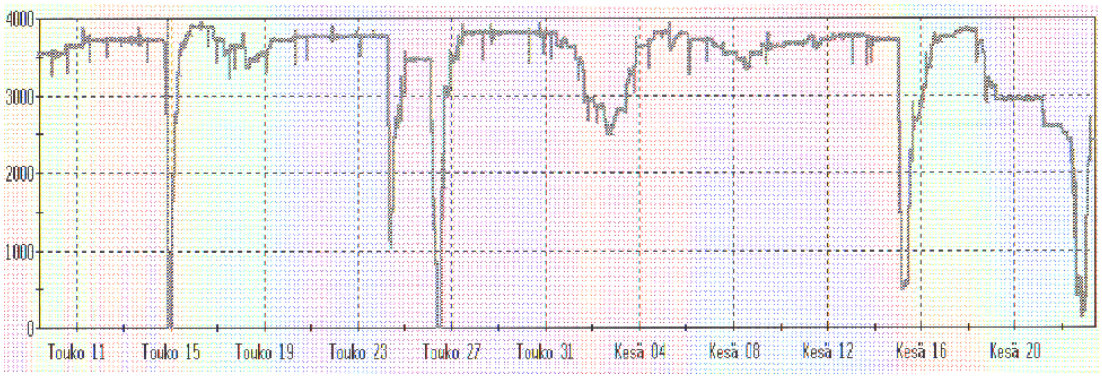
Instrumentation of the test device

The test probe was equipped with two thermocouples, which were installed vertically and horizontally in the middle of the top (3R12) and the lowest (HR11N) test pieces. 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. When the pressure was set at 8,8 bar(a) the upper thermocouple gave readings around 410°C. The pressure target value was increased to 9,2 bar(a) on 24th June 2010 at 3:05 pm in order to increase temperatures by few degrees.

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 a set point. The set point was selected so that the system pressure remained above 4 bars (with saturation temperature more than 330°C) all the time the probe was installed.

Operation of the recovery boiler during the test

In picture 1 is shown the boiler load during the whole test period. It can be seen that the boiler load stayed relatively steady.



Picture 1. Boiler load during the test period (tds/d).

Material temperature, oil temperature and system pressure during the test

In figure 1 is shown the thermocouple temperatures, calculated cooling oil saturation temperature and system pressure between 10th and 31th May before the leakage occurred in the cooling oil circuit.

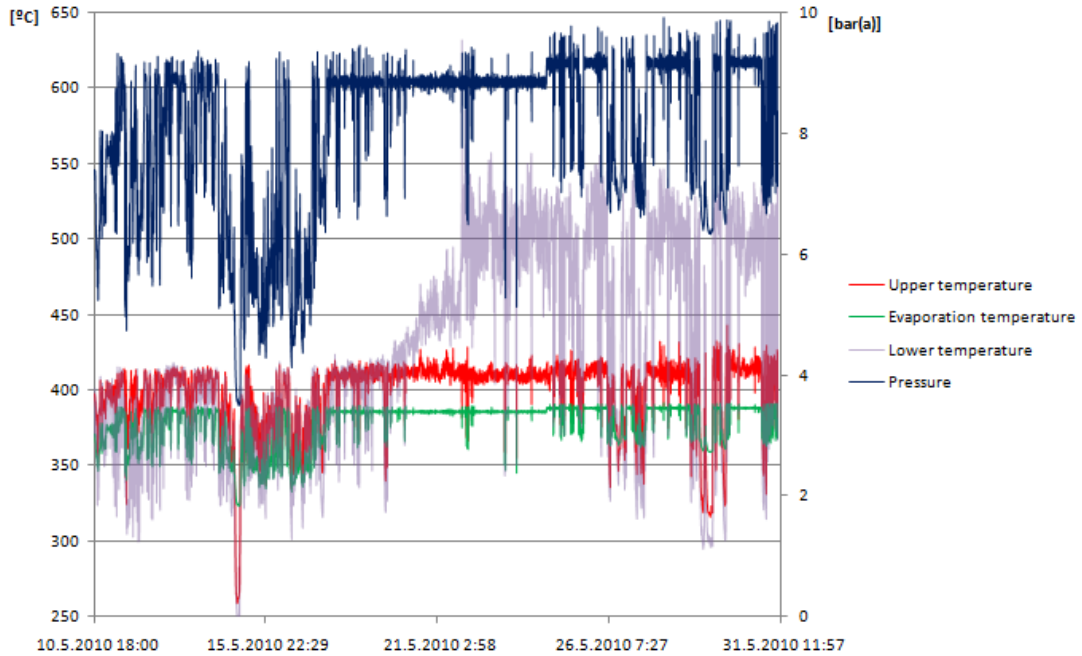


Figure 1. Thermocouple temperatures, system pressure and cooling oil saturation temperature 10. – 31.5.2010.

During the first week of the test the heat flux from the furnace to the tip of the probe wasn't strong enough which can be seen in rapid pressure drops and rises in figure 1 (demonstrated in blue). After one week of operation it was decided to increase one heating element's temperature which is clearly seen in instant rise in pressure. After that the pressure stayed closer to the set value also when the tip got covered with black liquor. When heat flux was steady the fluctuation in pressure was less than 0,5 bar.

The lower one of the two thermocouples broke down on 19th of May and the temperature readings started to climb slowly. That can be seen in figure 1 and is demonstrated in grey. The reason for the failure was probably inadequate casing of thermocouple.

A leak in the cooling oil circuit was discovered on 31th of May. The probe was pulled out from the furnace, cooled down until the next day, repaired and put back into the operation on first of June. After repair the test continued, see results in figure 2.

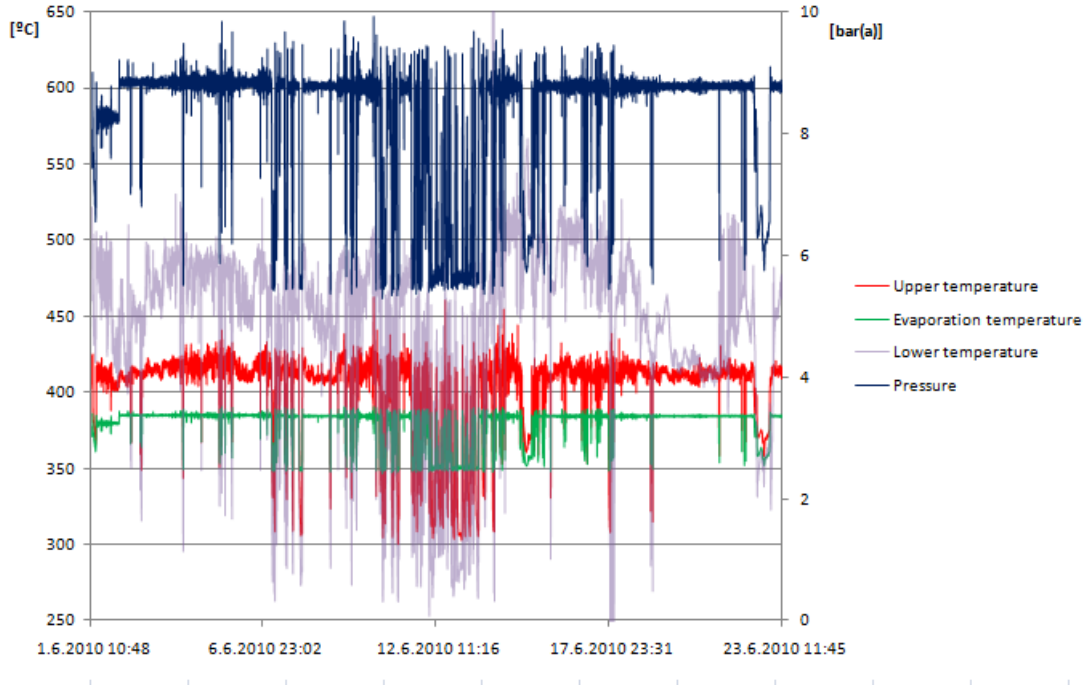


Figure 2. Thermocouple temperatures, system pressure and cooling oil saturation temperature 1. – 23.6.2010.

During the whole test period the system pressure stayed above 8 bar(a) 744 h, i.e. 73 % of the time. In the first experiment the system pressure was above 8 bar(a) 906 hours.

Material temperatures

Temperatures on test piece furnace side surfaces can be estimated by assuming that the heat flux to the tip of the probe is 205 kW/m^2 (as measured in previous tests in 2006), the heat transfer coefficient for 3R12 material at 400 °C is 22 W/m°C and for carbon steel 48 W/m°C and material thicknesses are 1,65 mm for cladding and 1,61 mm for carbon steel (the total carbon steel wall thickness is 4,88 mm). With these parameter values, the temperature difference between the tip of the thermocouple and test material surface (hot side) can be calculated to be 22°C.

The thicknesses for different test materials were selected so that the temperature difference over the different test pieces was the same.

According to thermocouple readings the temperature in the middle of the 3R12 test piece was between 400 – 440°C for 752 hours, i.e. 74 % of the whole duration of the test. The average temperature during this 752 hour period was 413°C. As surface temperature was about 22°C higher than the measured temperature, the estimated surface temperature in the test was 435°C for the 3R12 test piece, i.e. very close to the target value of 440°C.

Similar analysis cannot carried out for the lower test piece, as the lower thermocouple worked properly only for 216 hours. However, the measurement readings show that the temperature in the lower test piece followed closely that of the upper test piece with a slightly (about 2°C) higher values. This can be seen from figure 3, which shows temperature distributions of both thermocouples when the cooling oil pressure was close to its set value (> 8 bar(a)). The increased frequency of temperatures between 390 and 400°C is due to the fact that at the beginning of the test period the probe pressure fluctuated more that at later stages, as can be seen from figures 1 and 2. However, in this respect the readings of the lower thermocouple are not representative for the whole test period. Consequently, it is likely that the lowest test piece (material HR11N) experienced an average temperature of 435 - 440°C for about the same duration as the other test pieces.

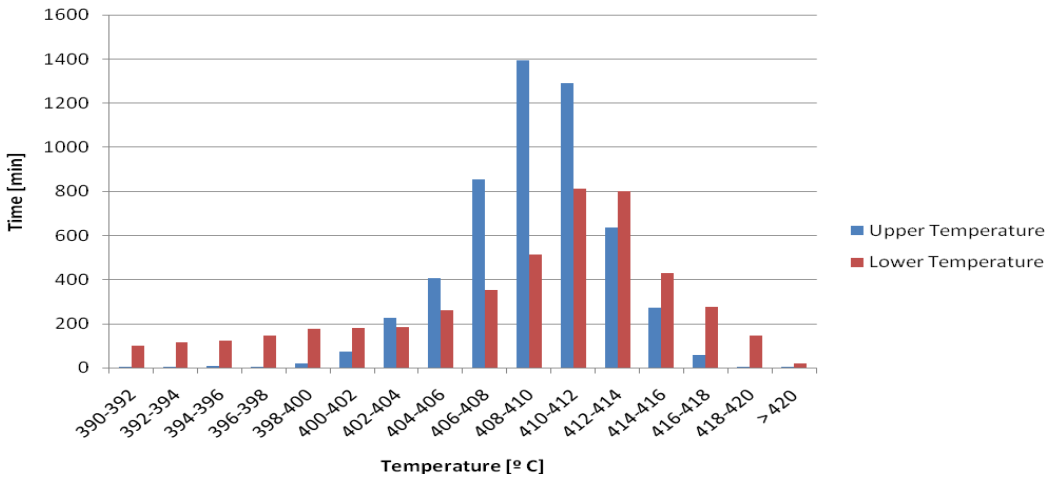


Figure 3. Temperature distribution of thermocouples when cooling oil pressure was close to its set value (> 8 bar(a)).

The maximum temperatures measured throughout the test were very moderate. The upper thermocouple readings exceeded the target material surface temperature 440 °C for 14 minutes with 462°C as maximum. The maximum reading in lower thermocouple during first 216 hours was 424 °C.

Summary

The measured average and maximum temperatures in the middle of the top test piece (material 3R12) were 413°C and 462°C during the periods when the probe pressure stayed close to the set value. Total time that the temperature stayed between 400 - 440 °C was 752 hours, i.e. 74 % of the time.

The estimated average surface temperature for the 3R12 test piece was 435°C for the period of 752 hours.

The measured temperatures in the middle of the lowest test piece (material HR11N) followed closely the temperatures of the upper test piece with a slight (2°C) difference in average temperatures.

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°C for a significant portion of the test duration and there were no uncontrolled excursion of material temperatures, the test was carried out successfully.