## Materials for Energy Technology

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# Microstructure analysis of HCM12 and HCM12A steels after 100000h exposition

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The two martensitic chromium steels HCM12 and HCM12A after 100 000h exposition at 550$^o$C of steam have been studied regarding microstructural changes using Scanning Transmission Electron Microscope (STEM).

These high-strength 12%Cr heat resistant steels have been developed for the boiler and turbine of an ultra-supercritical power plant, at a temperature higher than 550$^o$C.
The composition of HCM12 steel was follows: 0.1C-12Cr-1W-1Mo-0.25V-0.2Nb. While composition of HCM12A steel was: 0.1C-12Cr-2W-0.5Mo-0.25V-0.1Nb- Cu1.Tungsten, as the main alloying element, induces precipitation of intermetalic Laves phase during long –term exposure. $Fe_2W$ is thermally more stable than $Fe_2Mo$ [1,2]. It is also suggest that the addition of W retards recovery of martensitic lath structure [3].

In the as-received condition the microstructure of this kind of steel consist of tempered lath martensite with high dislocation densities, precipitated particles of relatively coarse $M_{23}C_6$ and fine MX in HCM12A and additionally islands of δ- ferrite about 30% surrounded by areas of tempered martensite in HCM12 steel. Mentioned steels were analysed in initial state and after exposure at 30 000h and 70 000h by authors of this article and the results of investigations are presented elsewhere [4,5].

Figure 1 shows a comparison of the microstructure in HCM12 and HCM12A after 100 000h. The HCM12 steel undergo a recovery and recrystallisation of the matrix. The recrystallisation starts by growth of dislocation free crystals at the former grain, martensite boundaries and especially at the ferrire grains. In HCM12A steel the recovery and recrystallization advances more slowly, for this reason the grains/subgrains in HCM12A steel are much finer than in HCM12. The reason for this behaviour is the precipitation of particles which retard the movement of the dislocation. The larger number of precipitates in HCM12A steel suppresses more effectively the recovery of grain/subgrain structure.

It has been found that the phases presented in the serviced conditions are $M_{23}C_6$, Laves phase and fine MX particles observed inside grain/subgrain. STEM-EDS analysis showed that the $M_{23}C_6$ were enriched in Cr, Fe, Mn, Mo, and W. Whereas Laves phase was enriched in W and Mo to have the general composition of the $(Fe,Cr)_2(Mo,W)$ (Figures. 2-4). Within the Laves precipitation, the stacking faults could be observed as a characteristic streaks on the electron diffraction pattern (Figure 2b). MX dispersed particles was enriched in V.

The Laves phase particles are located between an $M_{23}C_6$ moreover are situated in contact with the $M_{23}C_6$ precipitates (Figures. 2a and 3). Very often the agglomeration of Laves phase have been observed (Figure 2b). The observations performed in several microareas confirmed chromium concentration in the interior of Laves phase precipitation (Figure 2b). This is probably the effect precipitation of this phase on $M_{23}C_6$ carbides. Generally the coarsening intensity of precipitates is much larger in HCM12 than in HCM12A.

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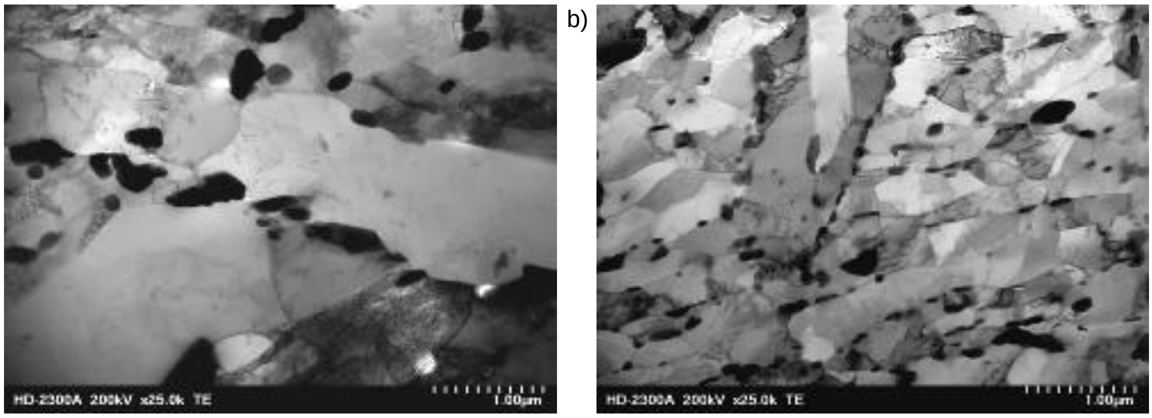


**Figure 1.** Microstructure of steels after 100 000h exposure a) HCM12 and b) HCM12A.

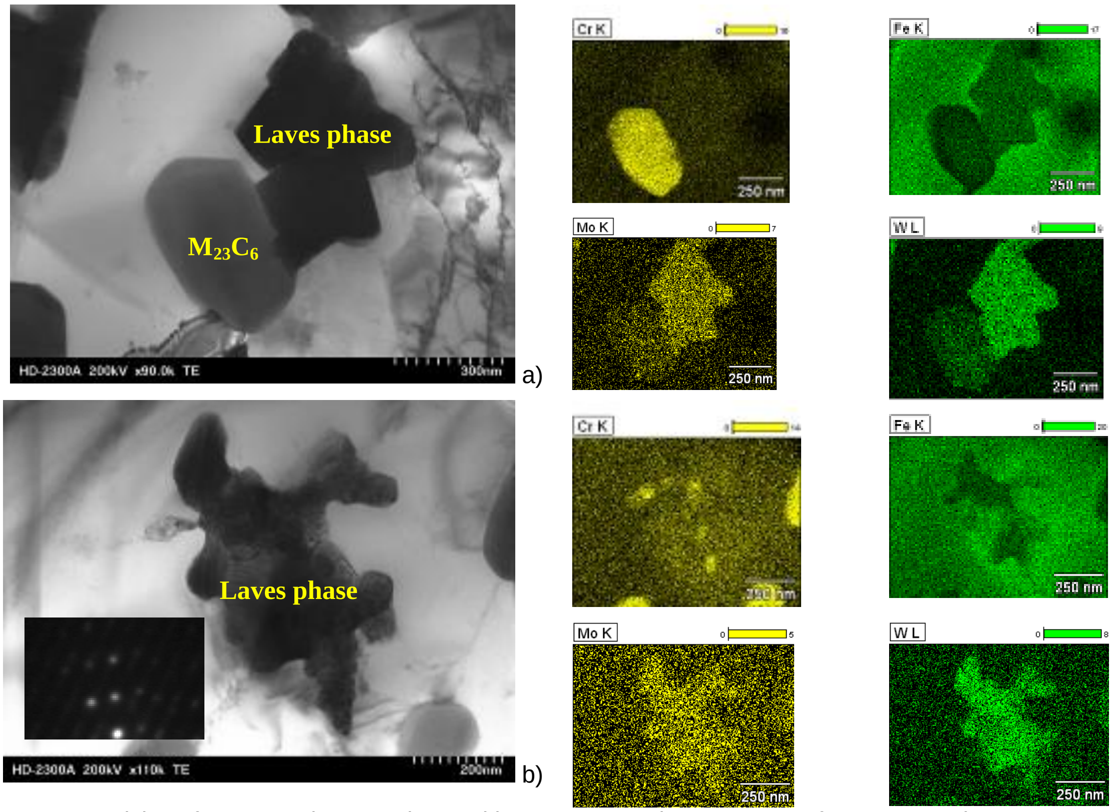


**Figure 2.** Particles of $M_{23}C_6$ and Laves phase with STEM-EDS element maps of HCM12 steel.

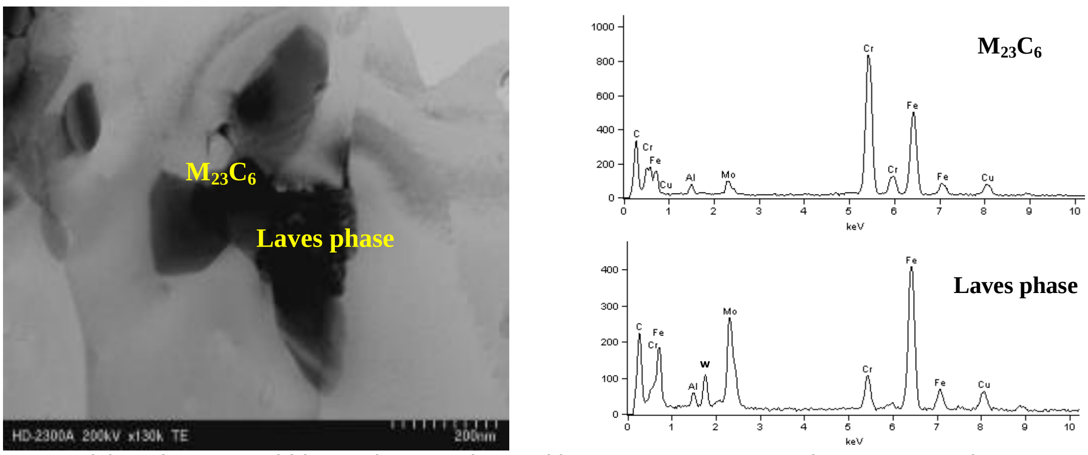


**Figure 3.** Particles of $M_{23}C_6$ carbides and Laves phase with STEM-EDS spectra of HCM12A steel.