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Microstructural Evolution of Cr-Mo Bainitic Steels During Tempering

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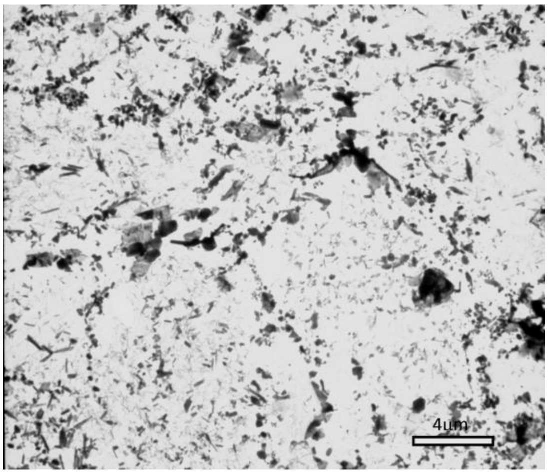
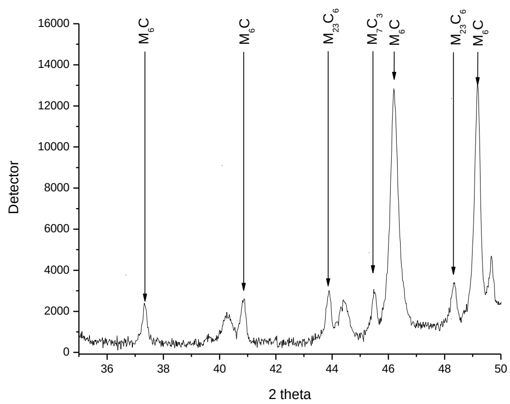
Abstract – The evolution of carbide precipitation in 2.25Cr 1Mo and 2.25Cr 1Mo 0.25V steels induced by artificial ageing at 600°C for 100h, 500h, 1000h and 2000h under inert and hydrogen rich atmospheres was studied. During tempering, the fine precipitates initially dispersed in the bainitic microstructure of both steels, evolutes to more stable carbides with higher molybdenum content and tent to coarse as well. The carbide evolution during ageing remains as a controversial issue in terms of alloys' composition, temperature, time and atmosphere of tempering. The precipitation sequences were studied by x-ray diffraction with synchrotron light source and the results were compared with TEM analysis using replica technique. The distribution and volumetric fraction of precipitates were also analyzed.

Cr-Mo steels are broadly used in chemical and petrochemical industries as base material for hydrocracking reactors. During service, these units operate at high temperatures under influence of hydrogen. At these conditions Cr-Mo type steels rely on the stability of their microstructures to avoid degradation and failure since carbide precipitation becomes the main hardening mechanism. Precipitation has been also associated with hydrogen trapping in 2.25Cr1Mo and 2.25Cr1Mo0.25V steels [1]. This phenomenon has an important role in hydrogen attack resistance for these materials.

The steels studied were obtained from 12 and 50 mm thick plates in the normalized and tempered condition. Samples of both steels were submitted to ageing heat treatments at 600°C for 100h, 500h, 1000h and 2000h under inert environment in quartz evacuated sealed tubes and hydrogen rich environment. Metallographic samples from each condition were examined in a scanning electron microscope and also analyzed using X-ray diffraction. Single stage replicas were observed with transmission electron microscope and energy-dispersive X-ray spectroscopy to identify and evaluate the precipitates.

In both steel, the precipitates initially present in the bainitic microstructures suffer, during ageing, considerably coarsening (Fig. 1 a). From the diffractions experiments in the 2.25Cr1Mo steel after 100h of ageing under inert atmosphere, the presence of $M_{23}C_6$ was observed as well as an increment on the intensity of M_2C's peaks. For heat treatment at 500h, M_6C could be also detected. With the increasing of time of treatment, M_6C shown a remarkable enlarge on its peaks combine with lower $M_{23}C_6$ ones until disappearing after 2000h of ageing. The heat treatment with hydrogen changed the microstructure, which produced an increase of M_6C's peaks and decrease the $M_{23}C_6$ peaks after 500h (Fig. 1 b). Under inert atmosphere, the carbides present on the 2.25Cr1Mo Vanadium modified steel exhibited more stability during ageing.





(a) **(b)**

Figure 1: 2.25Cr1Mo steel after 500h of ageing at 600°C under high purity hydrogen atmosphere. (a) TEM Replica and (b) DRX diffractogram.

References

[1] L. F. Lemus, J. H. Rodrigues, D. S. Santos and L. H. Almeida, Defect Diffus. Forum. 283-286 (2009) 370-375.