

A TEM STUDY OF THE PRECIPITATION EVOLUTION IN Cr-Mo AND Cr-W FERRITIC STEELS AND ITS RELATIONSHIP WITH CREEP BEHAVIOUR. Luiz Henrique de Almeida(1), Heloísa Cunha Furtado(2). (1)PEMM-COPPE/UFRJ – Metallurgical and Materials Engineering Program, Federal University of Rio de Janeiro, P.O.Box 68505, 21941-972, Rio de Janeiro, RJ, Brazil; (2)CEPEL, Centro de Pesquisas de Energia Elétrica, P.O.Box 68007, 21941-590, Rio de Janeiro, RJ, Brazil. Email: lha@metalmat.ufrj.br

Cr-Mo ferritic steels are widely used in petrochemical industry and in power generating stations in applications that involve exposure to high temperature, where creep and corrosion resistance are required. They are produced in the form of tubes, plates and structural components. The required resistance to creep is promoted by the addition of Mo and Cr while resistance to corrosion by Cr. To meet today's requirement of more efficient plants operating at higher temperatures and pressures, alloying elements such as Nb, V, Ti, Co and W are added. The more traditional alloy steels of the 1Cr-0.5Mo and 2.25Cr-1Mo type that have been in use for many years in steam generators and petrochemical plants have been supplemented in the recent years with the introduction of Cr-Mo steels containing from 9 to 12% of Cr, suitable for higher operating temperatures. More recently studies have been carried out to promote the partial or total substitution of Mo for W with the addition of other alloying elements, for example the Fe-3Cr-W(V) steel. As a general rule, the mechanical properties of Cr-Mo steels degrade over extend time as a function of the service temperature and applied stress. The principal degradation mechanism of these steels in high temperature applications is creep, which initially involves the spheroidizing and structural transformation of carbide precipitates and, at an advanced stage, results in the formation of voids and micro cracks. An important factor also affecting the creep properties of this type of steel is the carbide precipitation at the expenses of the reduction of Mo or W in solid solution. On the other hand creep data are of great importance in the design of components for elevated temperatures service. They are essential in developing data on allowable stresses for pressurized vessels and components at such operating conditions. Such data are always limited in extent and the experimental results of testing are subject to scatter caused by variations in properties between batches of the same nominal material as well as small variations among tests at nominally the same conditions. It is very difficult to provide experimental data for the projects service time, which may surpass the range of 200,000h (23 years)[1]. The prediction of long-time data obtained for design depends on the accuracy and validity of the predictive methods used, and interpolation and extrapolation procedures have been developed to facilitate this. Despite the advances in the predictive methods since the introduction of time-temperature parameters for extrapolating creep data almost half a century ago, problems of overestimation or underestimation of rupture time at longer time frequently occur. The majority of this overestimation or underestimation is associated with the accuracy of the data introduced for the calculations. They emerge from the effect of long-term microstructural stability and precipitation effects. Results in 9Cr-1Mo show that the reason for the problem of overestimation of rupture time is related to the presence of strengthening carbides and carbonitrides during the earlier part of the creep life and changes in the precipitate composition and morphology during the latter part of the creep life. It occurs because of the loss of the fine carbide precipitates that restrict dislocation movement during the greater part of the creep life. With longer periods of time, these precipitates are partially replaced by coarser carbide precipitates and the creep accelerates rapidly. Figures 1 and 2 confirm the presence of large M_6C carbides after the long creep times produced by transformation of fine carbides present at shorter times [2,3]. In Fe-3Cr-W(V) steel a drastic reduction in creep life is observed as a function of the precipitation of the intermetallic Laves phase. Figures 3 and 4 show the presence of Laves phase in a sample after artificial aging for 1000h at 650°C. The precipitation characterization through TEM using replication techniques, which is very practical and reliable for industries, can assist in the improvement of the creep data extrapolation procedures for this type of steel.

References:

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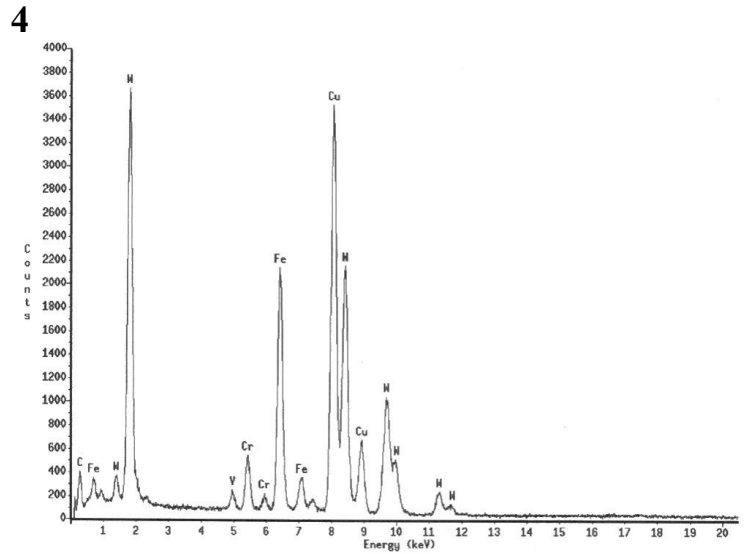
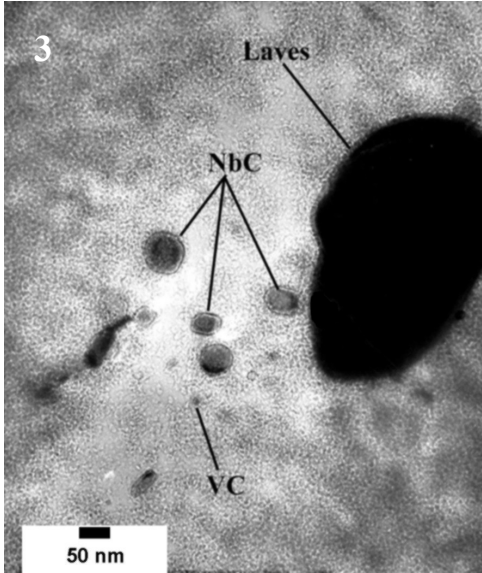
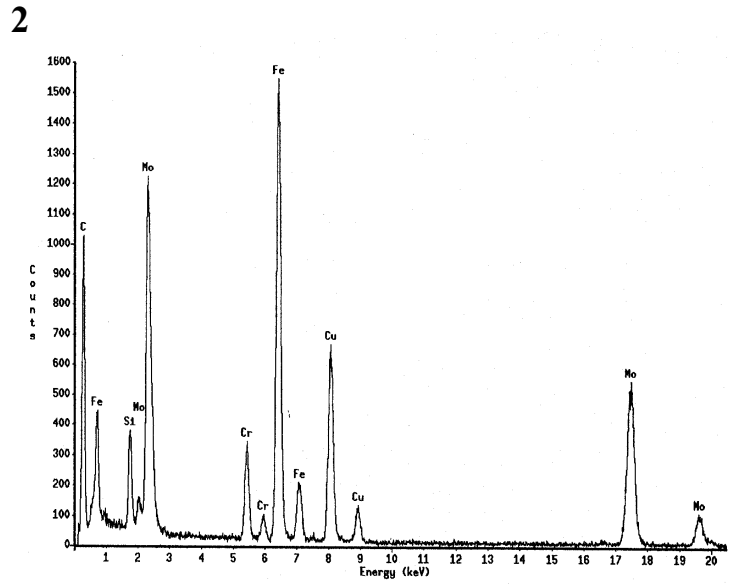
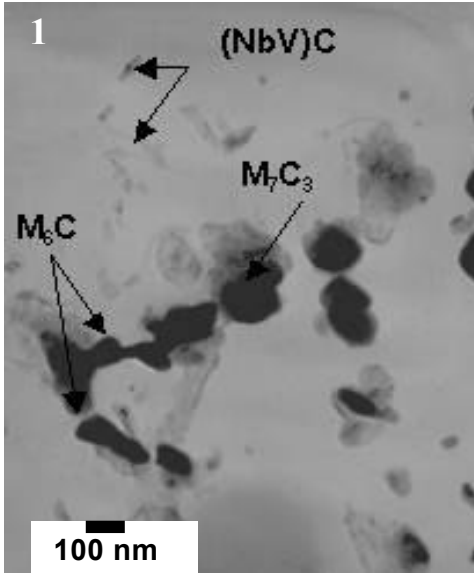


Figure 1 - TEM image of 9Cr-1Mo creep test sample fractured after 7,380h at 566°C.
(carbon replica sample)

Figure 2 - EDS spectrum of M₆C carbide observed in figure 1.

Figure 3 - TEM image of Fe-3Cr-W(V) steel creep test sample fractured after 1,000h at 650°C.
(carbon replica sample)

Figure 4 - EDS spectrum of Laves phase observed in figure 3.