Correction to: Austenite Grain Growth in a 2.25Cr-1Mo Vanadium-Free Steel Accounting for Zener Pinning and Solute Drag: Experimental Study and Modeling

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The authors found that the computer program developed to model grain growth contained an error arising from units conversion in the solute drag formulation. The error has now been corrected and the conclusion of the study remained unchanged, *i.e.*, the variation of grain growth behavior with the temperature is due to the solute drag of molybdenum. However, a constant parameter (the initial grain size), as well as an adjustable parameter (the binding energy at 1020 °C), were slightly readjusted and Figures 7, 8, 9 and 10 had to be modified. The corrected model shows that the mechanism responsible for the transition from limited growth to parabolic growth is different from what was previously thought.

Previous results showed that limited growth occurred at low temperature due to a transition from the high-velocity regime (the boundary motion being fast enough to inhibit the segregation of solute atoms) to the low-velocity regime (the boundary motion being slow down by the segregation of atoms) of the solute drag phenomenon. Corrected calculations showed that grain growth occurs in the low-velocity regime over the whole investigated temperature range (Figures 9 and 10). Transition from limited growth to parabolic growth is due to the evolution of the effective binding energy and of the diffusion coefficient of molybdenum with temperature, such that segregation of molybdenum atoms is negligible at high temperatures.

It is noteworthy to mention that the above considerations are in good agreement with current literature, where the solute drag phenomenon is usually considered to occur only in the low-velocity regime. Furthermore, the results are less sensitive to the choice of the time step, as shown by the Figure 8(a). Finally, calculations remain in very good agreement with the experimental results and with grain size measurements for 2.25Cr–1Mo steel available in the literature (Figure 9).

As a result, we would like to update the previously published article by indicating the corrections that must be taken into account. These are as follows:

The value of E_0 in Table V at 1293 K (1020 °C) is now − 0.38 eV.

On page 2297 parameter D_0 is changed from 20 to 25 μm.

Part of the discussion on top of page 2298, where the transition from high-velocity regime to low-velocity regime is mentioned should be modified as follows, since only the low-velocity regime is observed:

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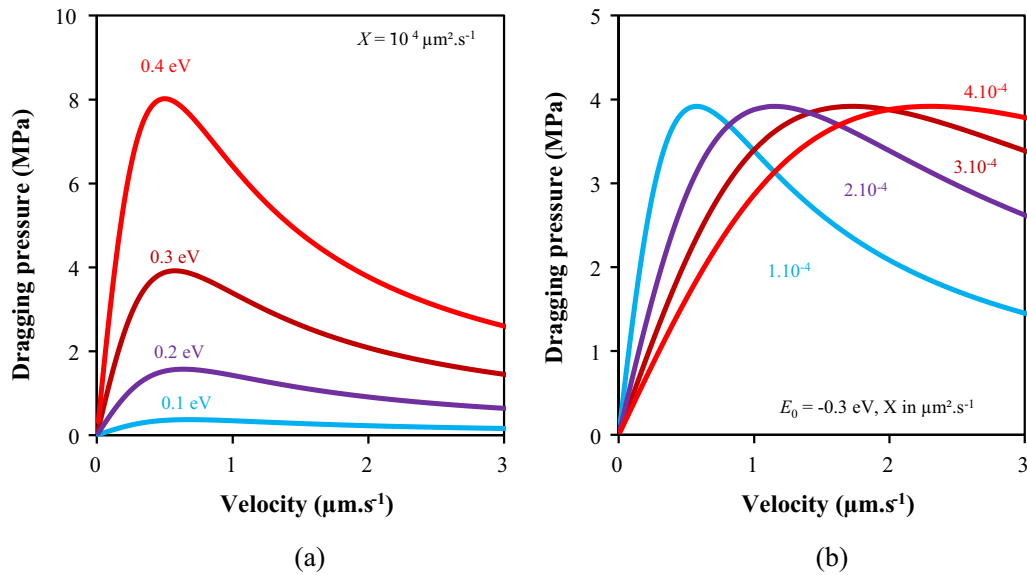
(a)

(b)

Fig. 7—Effect of the binding energy $- E_0$ (in eV) and of the diffusion coefficient X on the dragging pressure as a function of the grain boundary velocity.
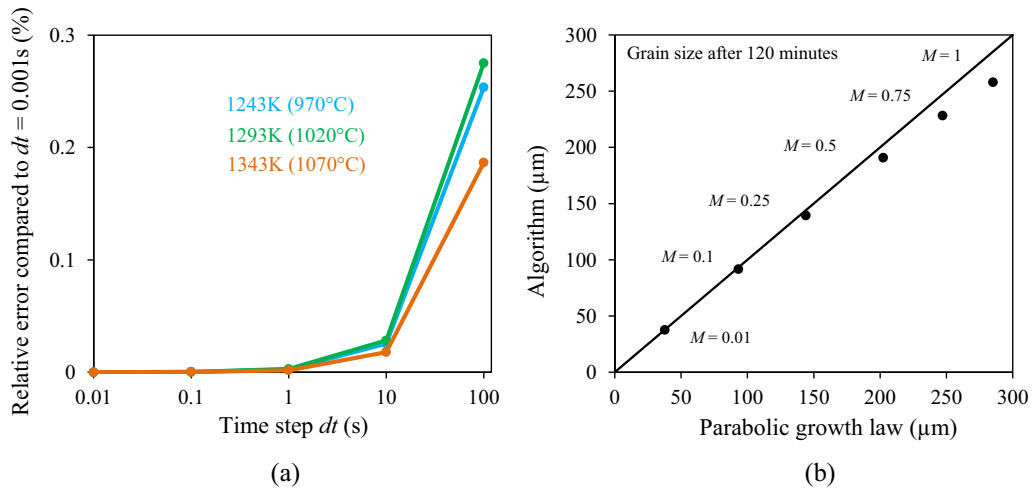

(a)

(b)

Fig. 8—Time convergence analysis for the algorithm at 1243 K (970 °C), 1293 K (1020 °C), and 1343 K (1070 °C) using the parameters given in Table V. Grain size were calculated for $t = 1000$ seconds (16.6 minutes) for time step ranging from 0.001 to 100 seconds. This duration was chosen as it corresponds to the time the limited growth begins (Fig. 2). (b) Comparison between austenite grain size for $t = 120$ minutes as predicted by the parabolic growth law and the algorithm for $E_0 = - 0.01$ eV, $T = 1173$ K (900 °C), $P_z = 10^{-3}$ MPa, and d$t = 0.1$ seconds. Mobility values are expressed in 10^{-12} m^4 J^{-1} s^{-1}.

Limited growth is due to the respectively large and low values of E_0 and X at lower temperatures, such that a large solute drag pressure is applied on the grain boundary, leading to a very slow growth. Increasing the temperature increases the diffusivity of molybdenum and decreases its binding energy, thus decreasing the solute drag pressure and increasing the growth rate. At higher temperatures, solute drag pressure becomes negligible and the growth follows a parabolic trend.

At the end of Section IV–C on page 2298, calculations performed for comparison with literature results are updated as follows:

It is noteworthy to mention that the predicted austenite grain size after 2 hours (120 minutes) at 1243 K (1070 °C) is 91 μm, in good agreement with the results reported in Table III (90 and 120 μm after 2 hours at 1323 K (1050 °C) and 1373 K (1100 °C), respectively).

At the top of page 2299, calculations performed for comparison with literature results are updated as follows:

At 1473 K (1200 °C), assuming that the solute drag is negligible and using a mobility as calculated with Eq. [3] and the obtained M_0 and Q parameters, the predicted austenite grain size after 2 hours of austenitization is
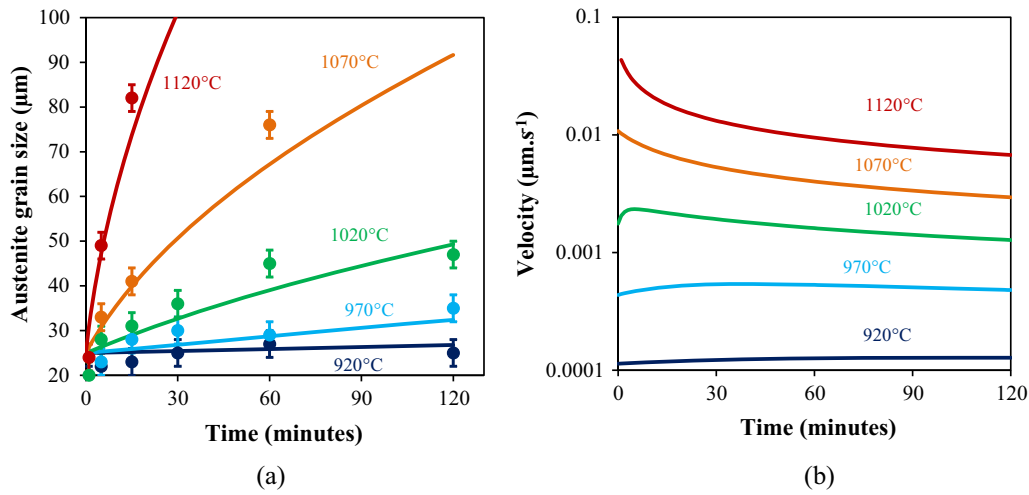
Fig. 9—Comparison between austenite grain size as predicted from calculations (continuous lines) and experimental measurements (symbols), (b) evolution of predicted grain boundary velocity with time for all temperatures.
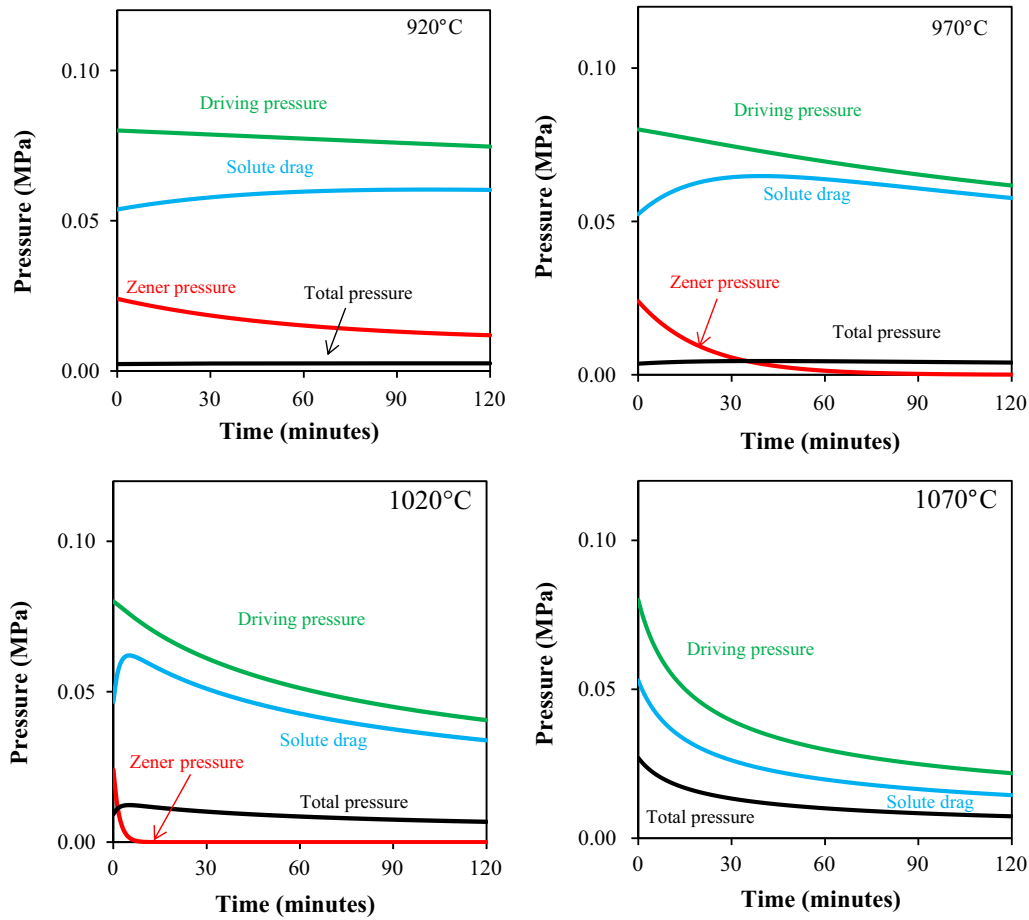

Fig. 10—Contributions from the different pressures exerted on the grain boundary at different temperatures.

307 μm. This value is in very good agreement with the result reported in Reference 8 in Table III, namely 310 μm for the same austenitization heat treatment.

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