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Partition and non-partition transition of austenite growth from a ferrite and cementite mixture in hypo- and hypereutectoid Fe-C-Mn alloys

M. Enomoto[a,d,*], S. Li[b], Z.N. Yang[c], C. Zhang[b], Z.G. Yang[b]

[a] Ibaraki University, Mito 310-8512, Japan
[b] Key Laboratory for Advanced Materials of Ministry of Education, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China
[c] National Key Laboratory of Science and Technology on Advanced High Temperature Structure Materials, Beijing Institute of Aeronautical Materials, Beijing 100095 China
[d] Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, Beijing 100083, China

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ABSTRACT

The growth of austenite from a ferrite and cementite mixture in low Mn steel of hypo- and hypereutectoid composition is investigated with focus upon the Mn partitioning between dissolving cementite (or ferrite) and austenite. Under the assumption that austenite is nucleated on cementite, two critical temperatures which characterize the transition between Mn-partitioned and non-partitioned growth of austenite are noticed; below the 1st and lower critical temperature the austenite grows with redistribution of Mn from the beginning, and above the 2nd and higher critical temperature, without Mn redistribution until completion. Between them the growth mode switches from carbon-diffusion to Mn-diffusion control during growth. The influence of carbon and/or Mn diffusion through the matrix becomes progressively more significant with time, but may not affect the growth mode transition temperatures. Above the 2nd critical temperature, which is at most ca. 50 °C higher than Acm or Ae_3 in alloys studied, the distribution of Mn in as-transformed or spheroidized pearlite is preserved at the completion of austenitization irrespective of the last dissolving phase, leading to the formation of an ultrafine mixture of martensite and austenite upon quenching.

1. Introduction

The development of advanced steel requires accurate and detailed knowledge about phase transformations and microstructural evolution during heating and cooling. The understanding of microstructural changes during heating is hampered presumably because the transformation kinetics and resultant microstructures are highly dependent upon the microstructure prior to heating, i.e. the morphology of constituent phases and the presence of carbides etc. [1–5]. Another reason for an apparently diverse transformation behavior in austenitization is that the diffusivities of carbon and alloy elements differ between ferrite (or martensite) and austenite by a few orders of magnitude [6]. As a result, the austenite growth is controlled by diffusion in the ferrite matrix at early stages, and by alloy element diffusion in austenite at later stages [7–10] whereas the diffusion in ferrite can often be ignored in austenite to ferrite transformation [11].

The growth of austenite from a ferrite and cementite mixture in alloyed steel is thus expected to be complicated because the diffusion of carbon and alloying element in ferrite (α), austenite (γ) and carbide (here cementite θ) is involved. Hillert [12] proposed to distinguish the austenite growth by occurrence or absence of the redistribution of alloy element as a guideline of discussion, applying the local equilibrium condition at the interface. In a number of subsequent studies [13–20] it has become clear that the local equilibrium hypothesis is useful for predicting the microstructure evolution during austenite formation which accompanies carbide dissolution in low alloy steels. Among the approaches so far made the present authors compared the carbon activities at θ/γ and γ/α interfaces and proposed a critical temperature designated partition to non-partition transition temperature (PNTT) [20]. Subsequently, they showed that this temperature depends upon the degree of partitioning of alloy element between ferrite and cementite which proceeds during pearlite transformation and post-transformation aging prior to austenitization heat treatment [21]. Furthermore, comparing simulation results with the experimental data on austenitization in a high carbon Mn-Cr alloy by Molinder [22], the 2nd critical temperature regarding the growth mode transition has been proposed [23].

In this report, the effects of Mn on the growth of austenite from a ferrite and cementite mixture are examined in low Mn steel over a wide range of carbon content. Whilst in austenitization of a high carbon steel

* Corresponding author: Ibaraki University, Mito 310-8512, Japan
E-mail address: masato.enomoto.fe6c7x@vc.ibaraki.ac.jp (M. Enomoto).

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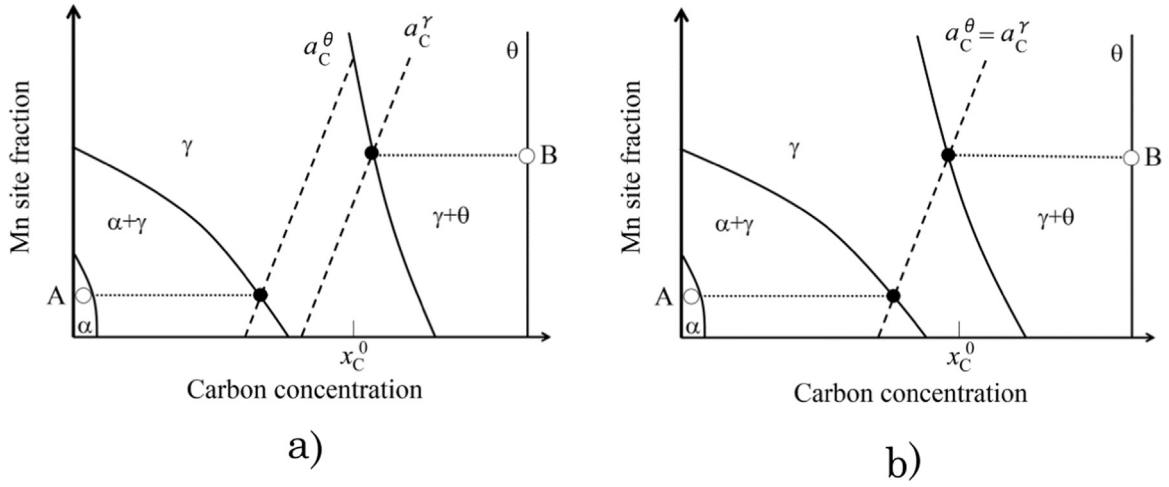

Fig. 1. a) Schematic illustration for the growth of austenite without redistribution of Mn. $a_C{}^\gamma$ and $a_C{}^\theta$ are the carbon activity at the γ/α and θ/γ interfaces, respectively ($a_C{}^\gamma < a_C{}^\theta$). The vertical axis is the Mn site fraction. b) $a_C{}^\gamma$ and $a_C{}^\theta$ become equal at PNTT-1.

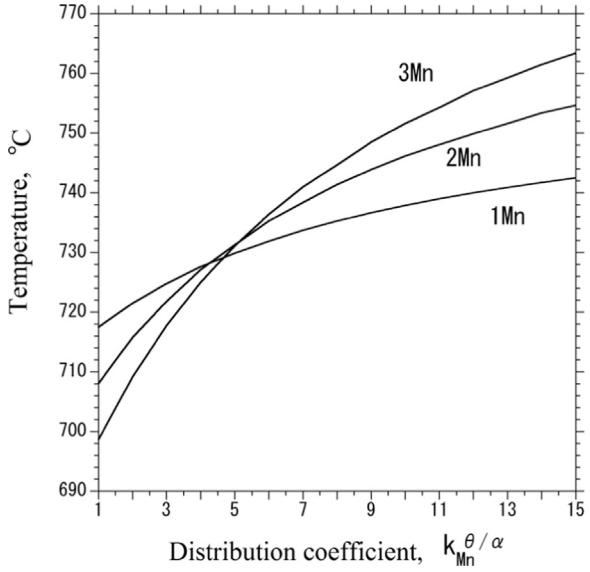

Fig. 2. Variation of PNTT-1 temperature with the extent of Mn partitioning in pearlite expressed by the distribution coefficient.

the last dissolving phase is cementite, in a low carbon steel cementite disappears first and the austenite growth is rate-controlled by Mn partitioning between ferrite and austenite at late stages. Accordingly, the austenite growth is simulated by DICTRA with MOB2 database [24] varying the carbon content from 0.3% to 1.1% (mass% unit is used throughout the paper). Moreover, the critical temperatures of the transition of Mn partitioning are calculated by Thermo-Calc with TCFE7 database [24] to delineate the basic features of the influence of Mn on austenite growth in these steels.

2. Transition temperature between Mn-partitioned and non-partitioned austenite growth

It is established that the austenite growth from a ferrite and cementite mixture occurs with redistribution of alloy element below a certain critical temperature, whilst it occurs without redistribution of alloy element above that temperature [12,20]. One can visualize the growth without redistribution of alloy element using carbon isoactivity lines passing through the composition at the θ/γ and γ/α interfaces in the isothermal section of the Fe-C-Mn phase diagram, see Fig. 1a. Given the initial composition of ferrite (A) and cementite (B), the austenite can grow without Mn redistribution if the carbon activity at the θ/γ

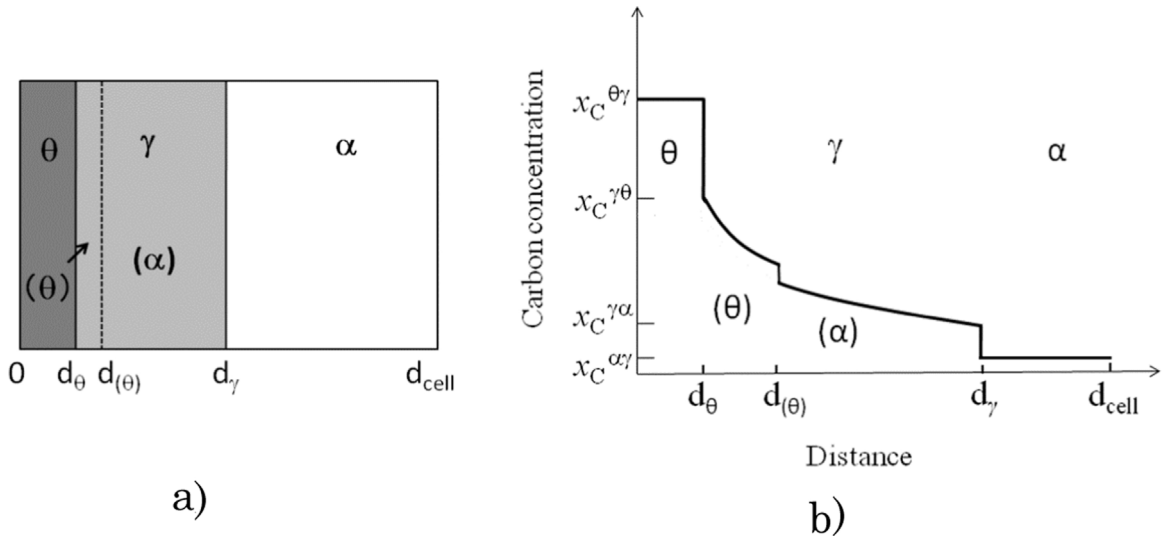

Fig. 3. a) Configuration of diffusion cell used in simulation, in which austenite is nucleated at all θ/α interfaces (denoted Cell A, $d_{cell} = 1$ μm), b) schematic illustration of carbon diffusion profile during the growth of austenite.