In-situ investigation of the austenitisation of Fe-C-Mn steel: influence of initial microstructure

V.A. Esin, B. Denand, Q. Le Bihan, J. Teixeira, M. Dehmas, G. Geandier, E. Aeby-Gautier, S. Denis

Institut Jean Lamour, Université de Lorraine, Parc de Saurupt, CS 50840, 54011 NANCY Cedex, France

Introduction

Several processes (rapid heat treatments, welding…) involve rapid heating and cooling conditions. During such processes, the steel may transform to austenite and the characteristics of the austenite (full or partial transformation, grain size, chemical homogeneity, etc.) at the end of the heating stage determine the further development of the final microstructure and, consequently, the final mechanical properties.

Classically, austenitisation has been studied through dilatometry [1-3] combined with microstructure characterisation after quenching, which leads to loss of essential information regarding the microstructure evolution at high temperature because of the austenite decomposition. To obtain a physical understanding of the sequence of events controlling the austenitisation, it is necessary to follow the evolution of microstructure in real time. To this aim, in-situ techniques for microstructure characterisation are being introduced, like confocal scanning laser microscopy and high energy X-ray diffraction (HEXRD). The latter technique recently allowed quantitative probing of essential microstructural features [4].

The main problem is related to investigation of carbides dissolution during the heat treatment. Indeed, often carbides play an important role during austenitisation since their dissolution requires more time than that for ferrite transformation into austenite. Moreover, after dissolution carbides leave carbon-reach zones in austenite.

In general, former investigations have been focusing on the effect of heating rate on the austenitisation process. In the present work, we investigated the influence of the initial microstructure on the kinetics of austenite formation on a single multi-component steel. Three initial microstructures have been used: ferrite-pearlite, bainite and tempered martensite, in order to makevary the nature and chemical composition of the phases, as well as the size and spatial distribution of ferrite “grains” and precipitates.

Results

The kinetics of austenite formation were characterized in-situ by both dilatometry (Bähr DIL 805A/D dilatometer) and high-energy X-ray diffraction (HEXRD), applying heating rates ranging from 1 to 100 °C/s. XRD data were interpreted using Rietveld analysis in order to obtain the amount of each phase and their unit cell parameters. Several aspects could be examined:

(i) In-situ tracking of the evolution of all the phases; influence of the initial microstructure

Figure 1 shows the evolution during heating at $60°C.s^{-1}$ of the mass fraction of austenite and cementite for the three considered initial microstructures: bainitic, tempered martensite and ferrite-pearlite. New outcome from these HEXRD experiments is the in-situ tracking of the cementite mass fraction evolution, which is not possible with conventional techniques such as dilatometry. Such measurements are necessary to interpret the kinetics of austenitisation, which is strongly dependent on the dissolution of cementite. By varying the initial microstructure, we made vary the size and the distribution of the cementite precipitates. It can be seen that the effect on the kinetics of austenitisation is significant. Comparing the results associated to each initial microstructure will help us to interpret the influence of the size and layout of the carbides.

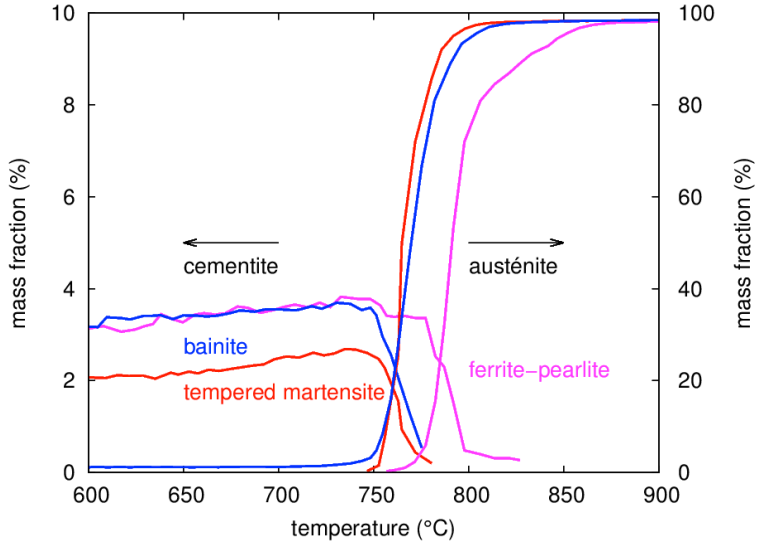

Figure 1: Mass fraction of austenite and cementite vs. temperature during heating at 60°C.s^{-1} according to HEXRD, for bainite, tempered martensite and ferrite-pearlite initial microstructures.

(ii) Comparison between HEXRD and dilatometry

Dilatometry is one the most common techniques to estimate phase transformation kinetics during treatments. By using the Bähr DIL 805A/D dilatometer, it was possible to perform simultaneously dilatometry and XRD, in order to examine the agreement between these techniques. Figure 2 compares for instance the evolution of the austenite mass fraction according to XRD and dilatometry, for the tempered martensite initial microstructure and a heating rate of 1°C.s^{-1}. It can be seen that the agreement between the two techniques is satisfactory in this case.

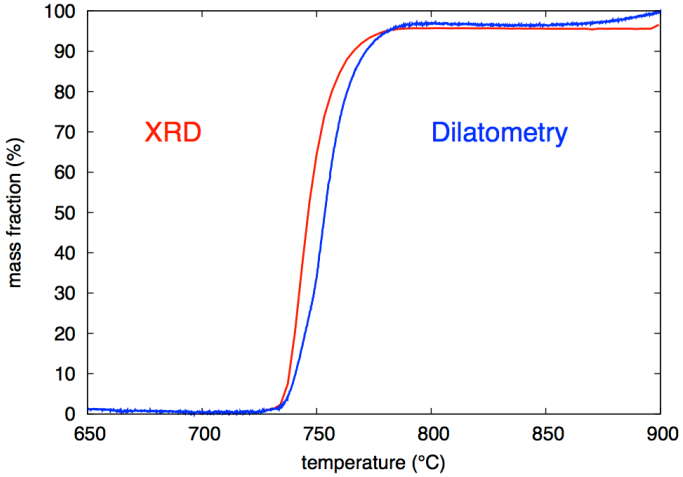

Figure 2: Mass fraction of austenite vs. temperature during heating at 1°C.s^{-1} of the tempered martensite initial microstructure, according to HEXRD and dilatometry.

References

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