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MATERIALS CHARACTERIZATION

# Kinetics of austenite formation during continuous heating in a low carbon steel

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**Abstract**

The kinetics and microstructural evolution of austenite formation in a low carbon steel, with initial microstructure composed of ferrite and pearlite, were studied during continuous heating, by using dilatometric analysis and measurements of microstructural parameters. The formation of austenite was observed to occur in two stages: (a) pearlite dissolution and (b) ferrite to austenite transformation. The critical temperatures of austenite formation in continuous heating increase with increasing heating rate, with greater influence on the finishing temperature of austenite formation. For both the 1 °C/s and 0.1 °C/s heating rates, the formation rate of austenite reaches a maximum at approximately the finishing temperature of pearlite dissolution, and the formation rate of austenite as a function of the temperature is greater at the higher heating rate.


*Keywords:* Low carbon steel; Austenite formation; Continuous heating transformation; Kinetics

## 1. Introduction

The formation of austenite in carbon steels is very important in commercial processes, because the steels are frequently processed in the austenitic field in some industrial steps. These include most thermomechanical and thermochemical treatments. The initial condition of the austenite determines the development of the final microstructure and the mechanical properties of the material. In this sense, the mechanical properties of the steels depend on the kinetics of austenite formation; in others words, they depend on the heating rate, austenite homogeneity, austenite grain size, non-metallic inclusions, and the distribution, size and chemistry of individual phases [1].

In recent years, several models describing the kinetics of austenite formation during heating have been proposed. Nevertheless, these studies are not as well developed as those for the decomposition of austenite into ferrite and pearlite during continuous cooling [2–4]. Since dilatometric analysis is a technique very often employed to study phase transformation kinetics in steels, the relative change in length which occurs during austenite formation has been studied as a function of temperature. Both kinetics and/or dilatometric analysis have been used to validate the model proposed for non-isothermal austenite formation in steels [5–7].

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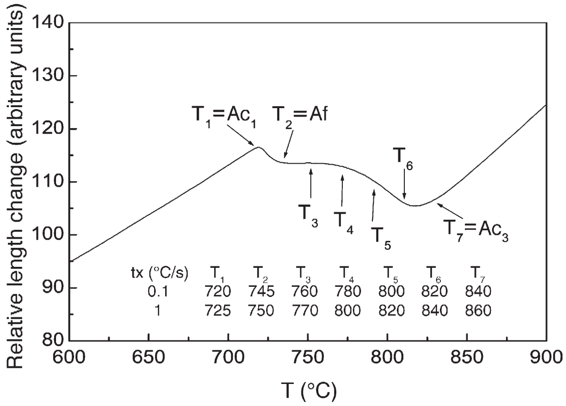


Fig. 1. Temperatures selected from heating dilatometric curves to investigate the progress of austenite.

The formation of austenite during heating differs in many ways from those transformations that occur during the cooling of austenite. The kinetics of austenite decomposition can be described satisfactorily in terms of the chemical composition and the austenite grain size, but the kinetics of austenite formation is influenced by chemical composition, initial microstructure and the heating rate [2–7].

This work analyzes the influence of the heating rate on the kinetics and microstructural evolution of austenite formation in the continuous heating of a low carbon steel with initial microstructure composed of ferrite and pearlite, by using dilatometric analysis and measurements of microstructural parameters. The continuous heating transformation diagram of the steel was also obtained.

## 2. Materials and experimental procedure

The chemical composition of the steel under investigation, expressed in wt.%, was 0.15C, 1.42Mn, 0.37Si, 0.052Al, 0.031Nb, 0.023P, 0.009S, 0.0042N, bal Fe.

The dilatometric analysis was carried out using an Adamel-Lhomargy LK 02 quenching dilatometer. Cylindrical 2 mm diameter, 12 mm long samples were used. The critical temperatures of austenite formation were determined from the dilatometric curves. The continuous heating transformation diagram was constructed for heating rates of 0.1, 1, 5, 10, 13 and 16 °C/s.

Several quenching temperatures were selected in order to investigate the progress of the austenite formation. Fig. 1 shows, on a dilatometric curve, the seven temperatures at which heating was interrupted by quenching (He gas). This procedure was performed in the dilatometer for heating rates of 0.1 and 1.0 °C/s.

The microstructural characterization was carried out by light microscopy and atomic force microscopy (AFM). The AFM images were obtained in Dimension 3000 equipment using commercial silicon tips in the tapping mode. The volume fractions of the constituents were determined with the aid of a digital image processing program, linked to the optical microscope. For examination of the microstructure, 2% nital and LePera's etchants [8] were used. Samples for AFM observations required fine polishing and a lighter etch.

## 3. Results and discussion

The initial microstructure of the samples consists of pearlite and ferrite (volume fraction of 0.73±0.03) and an average grain size of 18±0.6 μm.

### 3.1. Continuous heating transformation diagram (CHT)

The dilatometric curve of length change as a function of temperature, $\Delta L/L_0=f(T)$, and its corresponding derivative, $d(\Delta L/L_0)/dT=f(T)$, is illustrated in Fig. 2 for the heating rate of 1 °C/s. The critical temperatures $Ac_1$ (starting temperature of austenite formation), Af (finishing temperature for the dissolution of pearlite) and $Ac_3$ (finishing temperature of austenite formation) are indicated in the figure. It is observed that austenite formation occurs in two stages. The first stage is the pearlite dissolution and is characterized by the first peak of contraction in the dilatometric curve. It starts at $Ac_1$ and finishes at Af. The second stage is the ferrite to austenite transformation and is characterized by the second peak of contraction. It starts at Af and finishes at $Ac_3$. Both transformations take place by nucleation and growth processes.

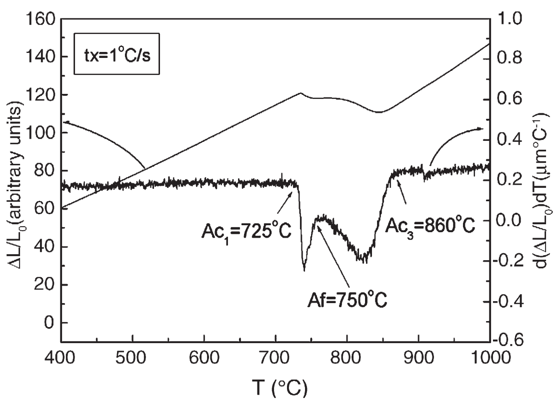


Fig. 2. Dilatometric curve of length change as a function of temperature and its corresponding derivative, for the heating rate of 1 °C/s.