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Estimation of the Volume Percent of Normal and Nanostructured Bainite in Bainitic Steels

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Abstract

Estimation of the volume percent of bainite has been conducted using a powerful computational technique known as neural network. The model is proposed for ordinary bainitic steel in addition to the more recent class of super bainite steel which are attractive for many applications. The model has been checked for a wide range of steels, including super-bainite steels. The proposed model is based on chemical composition, heat treatment and hardness. The predicted results have shown good agreement with the experimental results.

Keywords: Volume percent of Bainite, , neural network, modelling.

1. Introduction

Bainite is formed during the decomposition of austenite by isothermal transformation in a temperature range where neiher pearlite nor martensite form. The steels which have been studied have a microstructure containing in general a mixture of carbon free bainitic ferrite, austenite and some martensite. The large concentration of silicon typically present in bainitic steels is a key in the development of this fine microstructure. The silicon hinders the precipitation of cementite during the bainite transformation [1].

One of the most common hardening heat treatments is isothermal transformation. The isothermal process to form bainite is defined in two stages, the first involved the formation of bainitic ferrite and the second the decomposition of carbon-enriched austenite into cementite [2]. Between the two stages, there is what is called “a processing

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window" where heat treatment can be conducted without danger of carbide precipitation, fig 1. The first stage starts without any bainite and at the end of stage I, both bainite and retained austenite contents are maximised. In the second stage, further bainite does not form but continuous carbide precipitation leads to a reduction in the amount of austenite [3]. The isothermal transformation temperature defines the maximum volume fraction of bainite that can be observed [4]. There are two previous artificial neural networks to estimate the volume percent of retained austenite. The first model was intended to create a mechanism-based model capable of estimating the maximum volume percent of austenite in austempered ductile irons [5]. The intention of the second model was to estimate the amount of retained austenite in transformation-induced plasticity assisted steels [6, 7]. These two models have been published and were used to optimize the microstructure of these steels. No model was found which is based on neural network to estimate the volume percent of bainite. Some models dealt with the kinetics of the bainite transformation, such as the physical mechanism of transformation [8, 9]. In this work, a neural network model is proposed to estimate the volume percent of bainite for a wide range of steels as a function of chemical composition, austenitisation temperature, isothermal transformation temperature and vickers hardness.

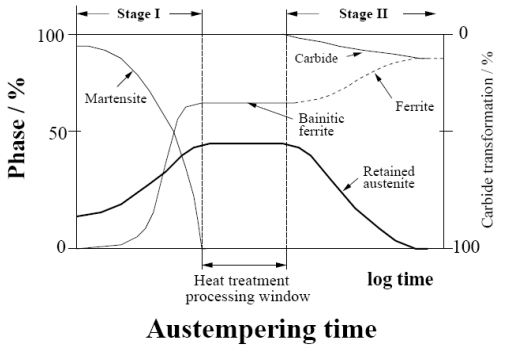

Fig.1. Schematic representation of the development of microstructure during austempering, together with an illustration of the "processing window" [3].

2. The method used

2.1. Inputs

The model was built by analysing a dataset which is based on experimental results published in an atlas of isothermal transformation diagrams [10]. The set of inputs is shown in table 1. A total of 449 experimental data were collected from [10], including information about super-bainite [11-14]. Some values of martensite-start temperature were calculated from the program mucg-73 if they were missing from the publish set [15]. The data were only collected for the isothermal transformation process to form bainite; direct quenching or tempering data were excluded in this dataset. Fig 2 shows the distribution of inputs against the volume percent of bainite.

Table 1: The variables in the dataset.

Parameter	Minimum	Maximum	Average	Standard deviation
C / wt%	0.11	1.08	0.58	0.34
Si / wt%	0.09	1.57	0.29	0.27
Mn / wt%	0.30	2	0.72	0.38
Ni / wt%	0.00	4.33	2.03	1.45
Cr / wt%	0.10	1.55	0.87	0.39
Mo / wt%	0.01	1.05	0.25	0.27
Transformation temperature / °C	190	750	485	142
Ms / °C	53	455	257	115.3