MODELLING THE MICROSTRUCTURAL EVOLUTION DURING HOT ROLLING

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***Abstract*-- A metallurgical model that describes the microstructural evolution of C-Mn steels in the hot strip mill, and that predicts the yield strength and the ultimate tensile strength based on the steel chemistry and the processing conditions is presented. The model comprises the microstructural evolution during hot deformation in the austenitic range (taking into account the effects recrystallization and grain growth), and the austenite decomposition during cooling (formation of ferrite, perlite and/or bainite). A comparison between calculated and measured yield strength and ultimate tensile strength values for several steels and processing conditions is also included.**

***Keywords*-- hot rolling, recrystallization, grain growth, phase transformation.**

I. INTRODUCTION

Improving the hot strip mill process is mandatory for the steel industry owing to the increasingly severe specifications being imposed by end users. Within this objective the development of a metallurgical model that links the operating variables in the mill with microstructure and mechanical properties of the final products becomes of great importance. This model could provide useful information for process control and optimization, reducing the need of costly on-line experimentation.

The aim of this work is to present a metallurgical model that could describe the microstructural evolution of C-Mn steels during hot rolling, and could predict the final mechanical properties based on the steel chemistry and the processing conditions.

During hot deformation the average dislocation density of the material increases several orders of magnitude. Two metallurgical processes become active to reduce the dislocation excess: recovery and recrystallization. In austenite, the later is the most important restoration process. Depending on temperature, strain and strain rate the recrystallization could begin during deformation (dynamic recrystallization) or in the interpass time (static recrystallization). In order to describe the microstructural evolution it is needed a description of the recrystallization progress and the resulting austenite grain size after each reduction step in the rolling mill. In addition further modifications of the grain size could take place if the recrystallization after deformation is complete and is followed by grain growth.

After hot deformation the austenite transforms to ferrite, perlite and/or bainite. The transformation kinetic and final phase distribution depend strongly on the austenite microstructure (grain size and accumulated strain), and on the cooling and coiling conditions. Due to the important metallurgical differences between the several phases that may appear, it is needed an accurate description of the final microstructure in order to evaluate the mechanical properties of the material.

II. EXPERIMENTAL PROCEDURE

Stress relaxation tests (Liu and Jonas, 1988) performed with a Gleeble 3500 thermo-mechanical simulator have been used to measure the kinetic of recovery and recrystallization for different processing conditions (deformation temperature, strain and strain rate). In order to study the recrystallized grain size and the kinetic of grain growth, samples were deformed in compression and quenched after different holding times. The boundaries of the prior austenite grains were revealed using standard metallographic methods.

Dilatometric tests were also performed in the Gleeble machine to study the kinetic of austenite decomposition into ferrite, perlite and/or bainite.

Several low carbon–manganese steels were analyzed, the chemistries were within the following ranges [C] = 0.09-0.17 wt%, [Mn] = 0.8-1.2 wt% and [Si] = 0.1-0.3 wt%.

III. HOT ROLLING MODEL

In the present model the average grain size and the accumulated strain have been used to characterize the microstructure of the steel in the austenitic range. For the calculation of the microstructural evolution during hot deformation we have considered the effects of recrystallization and grain growth.

If the accumulated strain in a single reduction is lower than the critical value (ε_c) for the initiation of dynamic recrystallization, static recrystallization proceed after deformation (interpass time). The kinetic of static recrystallization was modelled using an Avrami type equation as proposed by Sellars (1980):

$$X = 1 - \exp\left[-0.693\,(t/t_{0.5})^n\right] \qquad (1)$$

where X is the volume fraction of the material recrystallized, $t_{0.5}$ is the time to 50% recrystallization and n is an empirical parameter. Several expressions have been