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بسم الله الرحمن الرحيم

HANAA ALY

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قسم

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HANAA ALY

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Design and Production Engineering

Thermomechanical processing and deformation behavior of dual phase steel

A Thesis submitted in partial fulfillment of the requirements of the degree of

Doctor of Philosophy In Mechanical Engineering

(Design and Production Engineering)

By

Hany Abd AL Rahman Khalifa

Master of Science In Mechanical Engineering
(Design and Production Engineering)
Faculty of Engineering, Ain Shams University, 2013

Supervised By

Prof. Dr. Mohamed Ahmed Taha

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Dr. Gamal Mohamed Megahed

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Statement

This thesis is submitted as a partial fulfillment of Doctor of Philosophy in Mechanical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Signature

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Date:

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Abstract

The current work developed two grades of direct hot rolled ultralow carbon dual phase steel, ferrite bainite dual phase “FBDP” and ferrite martensite dual phase "FMDP” steel with high ductility values. The alloy design and production route cope with a compact slab production CSP plant. Ultralow carbon alloys were determined within the pre-peritectic region from phase diagrams plotted by Thermo-Calc 2020. The chemical compositions of the alloys are 0.045% C, 0.28 Si%, 0.91% Mn, and different Cr weight contents of 0.59%, 1%, 1.56%, and 2%. These alloys were used to develop FBDP steel. Analogous to "FBDP" steel, the martensitic dual phase steel is developed using ultralow carbon alloy and the only difference is the addition of niobium. The chemical composition of FMDP steel is (0.045 Wt.% carbon, 0.04 Wt.% niobium, 0.59 Wt.% chromium, 0.9 Wt.% manganese, 0.28 wt.% silicon) . These alloys were melted and cast into blocks, and then a certain thermomechanical schedule was applied using the actual data obtained from the log files of a CSP plant. The cooling schedule was designed with the aid of CCT and TTT curves plotted by JMatPro. The designed thermomechanical processing scheduled was performed by two methods. In the first method physical simulator "Baher TTS 820" is used. This device allows to perform physical simulation of direct hot rolled dual phase low carbon steel by varying the metallurgical temperatures and deformation parameters of to simulate compact slab production plant CSP. The second method is the pilot scale rolling and salt bath heat treatment, this route is used to develop FBDP steel under specific conditions determined from the results of physical simulation of the thermomechanical processing. The niobium was added to the FMDP steel to enhance the ductility of the martensite DP steel, since the current work aims to get high ductility values of DP steel, while lower carbon content is enough to get high ductile FBDP steel. The micro alloying affects the hot deformation flow behavior of the steel and the final microstructure. Consequently rheological curve characteristics under different rolling conditions are predicted using data of compact slab production log files and the phenomenological hyperbolic sinusoidal Arrhenius mathematical model. The Practical values of high strain rates reaches to 100 S^{-1} along with the practical deformations temperatures of an industrial hot strip mill plant are used. Mean flow stress, non-recrystallization temperature and microstructure grain size are investigated. The results show that hot rolled FBDP steel contains a substantial amount of bainite from 10 to 28% and negligible martensite. The increase in Cr led to an increase in the bainite volume fraction and an increase in the yield strength and tensile strength, while the elongation decreased slightly. The strain hardening exponent (n-value) reached values ranging from 0.28 to 0.36, while a value of 0.18 was found in the literature for martensitic DP steel. Stroke-force curves plotted from the Erichsen test achieved high Erichsen index values from 14 to 18mm. The results of FMDP steel shows that the increase of finishing rolling temperature from 780 °C to 840 °C or decreasing either of step cooling duration at ferrite bay from 7 to 4 seconds, enhances yield and tensile strengths, all due to more martensite volume fraction formation. The yield and tensile strengths also increase with decreasing coiling temperature from 330 °C to 180 °C, which is explained due to the increase of dislocation densities resulted from the sudden shape change during martensite formation at the lower coiling temperature in additional to the self-tempering of martensite formed at higher coiling temperatures which soften the dual phase steel. The numerical analysis of flow behavior shows that predicted values of mean flow stress and non-recrystallization temperature are in a good agreement with the values obtained from the straightforward method by mathematical integration of the flow curves predicted by (BährTTS820) thermomechanical simulator. Predicted grain size shows good agreement with industrial rolled specimen microstructure. Predicted flow curves show good agreement with those directly plotted from physical simulation data.

Keywords:

Dual phase steel, Thermomechanical processing, Hot Rolling, Isothermal holding, Physical simulation, bainite, martensite.

Table of Content

List of Figures