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EFFECT OF ANNEALING TEMPERATURE ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF HOT-DIP GALVANIZING DP600 STEEL

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Abstract

Hot-dip galvanizing dual phase steel DP600 steel grade with low Si was produced by steel plant and experiments by simulating galvanizing thermal history. The microstructure was observed and analyzed by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The effect of different annealing temperatures on the microstructure and mechanical properties of dual-phase steel was also discussed. The experimental results show that the dual-phase steel possesses excellent strength and elongation that match EN10346 600MPa standards. The microstructure is ferrite and martensite. TEM micrograph shows that white ferrite with black martensite islands inlay with a diameter of around 1um and the content of 14～18%. The volume will expand and phase changing take the form of shear transformation when ferrite converted to martensite. So there are high density dislocations in ferrite crystalline grain near martensite. The martensite content growing will be obvious along with annealing temperature going up. But the tendency will be weak when temperature high.

Introduction

Safety and energy consumption are the primary troubles for the automotive industry, and the use of high strength steels can reduce the problems. The galvanizing dual-phase steel possesses low yield point, high initial work hardening, good corrosion resisting, excellent strength and elongation, which is applied more and more widely [1]. The production processes include steelmaking, hot-rolling, cold-rolling, annealing and galvanizing. This article discussed the relation between production parameters and structure attained by SEM and TEM which were used to observe the dual-phase steel produced by Hansteel and annealing simulating equipment.

Experimental Procedure

The experimental steel has the characteristic of low carbon, high manganese and low silicon. The welding performance and zinc coating adhesion will be bad when silicon content is high. The molybdenum and chromium can enhance quenching effect and avoid pearlite generating. So the chemical composition of the experimental steel is given in Table 1.

Table1 Chemical Composition of Tested Steel, wt%

C	Si	Mn	S	P	Alt	Mo+Cr
0．05～0.10	＜0.10	0.8～1.2	≤0.010	≤0.014	0.035～0.055	＜0.5

The slab was heated to 1220℃ being held up to 50min. After 3+3 rolling procedure by rough mill, the slab temperature will reach 1130℃ before enter finishing mill. The finishing temperature is 840℃ and coiling 610℃. The cold-rolling reduction is 60%. Then the specimens got from the product were in dimension of 1.2mm × 50mm × 210mm. Hot-dip galvanized annealing process was held in the equipment with type CCT-AY-II, and the temperature is 760℃,780℃,800℃,820℃, respectively, with annealing curve given in Fig.1. The steel will be cooled to 690℃ at a low speed, which is propitious to martensite generating.

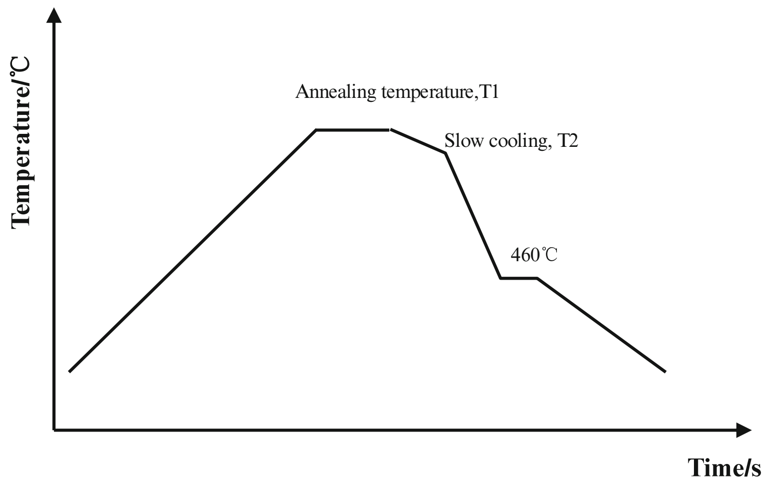


Fig.1 Hot-dip galvanized annealing process

Results and Discussion

The mechanical properties of annealed steel were showed in table 2. The test method is based on EN10346 and the tensile machine is Zwick/Roell Z100.

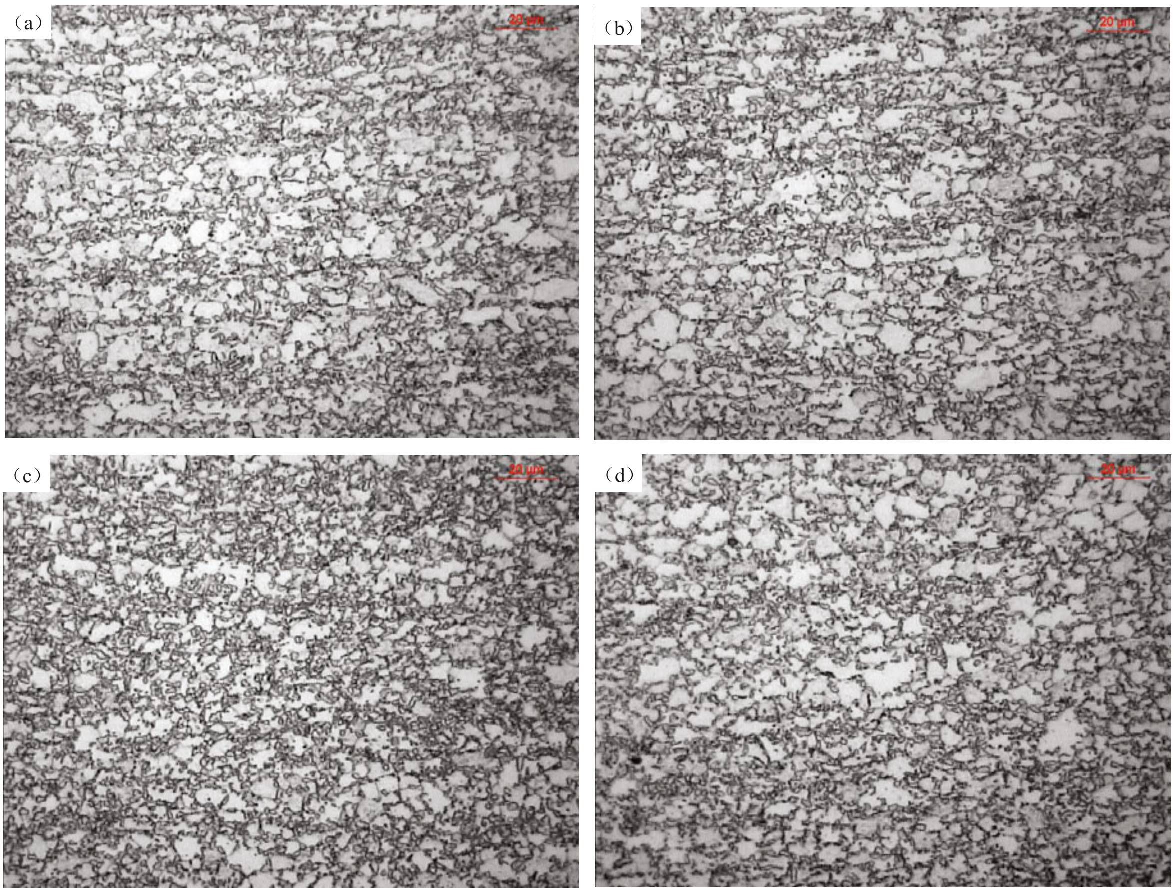
Table 2 Mechanical Properties of Experimental Steels

No.	Temperature /℃	Re/MPa	Rm/MPa	A_{80}/%	Yield Ratio
G1	760	362	606	25	0.60
G2	780	370	631	24	0.59
G3	800	384	658	22	0.58
G4	820	377	650	22	0.58

The experimental steel possesses high tensile strength, excellent elongation and low yield ratio. When tested, the specimens' stress-strain curves are smooth with no yield point and zone. The tensile strength is above 600MPa and elongation 20%, yield ratio below 0.60, which meet the requirements of EN10346 for DP600.

The tensile strength presents ascending trend according to temperature. When annealing temperature is 800℃, the tensile strength reaches the highest of 658MPa. But when temperature higher, the strengths go down a little. The lithe ferrite makes for the ductility of dual-phase steel when martensite for the high strength. Steel at different annealing temperature, the austenite volumes are different. In general, when temperature was high, the austenite volume came to be high. Accordingly, the martensite coming from austenite came to be more. But, the hardenability became weak when austenite volume too large. The result is that the tensile strength will be low.

Fig.2 shows the microstructures of experimental steel under different heat treatment conditions. The dual-phase steel comprises ferrite and islands of martensite from optical microscope micrographs. The most martensites occupy the crystal boundary, only some scatter inside the grain of ferrite.



(a)760℃；(b)780℃；(c)800℃；(d)820℃

Fig.2 SEM images of the steel at different annealing temperatures

The ferrite crystal particles became smaller when annealing temperature went high. Because when temperatures go high, the phase α and γ atomic diffusion activation energy will go up, too. The nucleation quantity will increase then when crystalloid internal energy rises. So the recrystallization nuclei of grain will become more and more. The carbide, nitride and impurity can become more dispersive when annealing temperature high, which make recrystallization nuclei amount more, too. This two aspects make more fine crystal particles when recrystallization happening at the two phase region. And the austenite transforms to martensite when steel being cooled.

The mechanical characteristics of dual-phase result from the soft ferrite phase and stiff martensite. The volume, pattern and distribution of martensite can result in different tensile strength. Fig.3 shows the martensite volume percentage at different annealing temperature, using the point method and image analyzer. The numerical value is 14～18%. The percentage ascends according to the annealing temperature. The volumes at the temperature of 800℃ and 820℃ are nearly the same, which also proves that the volume decides the steel strength.

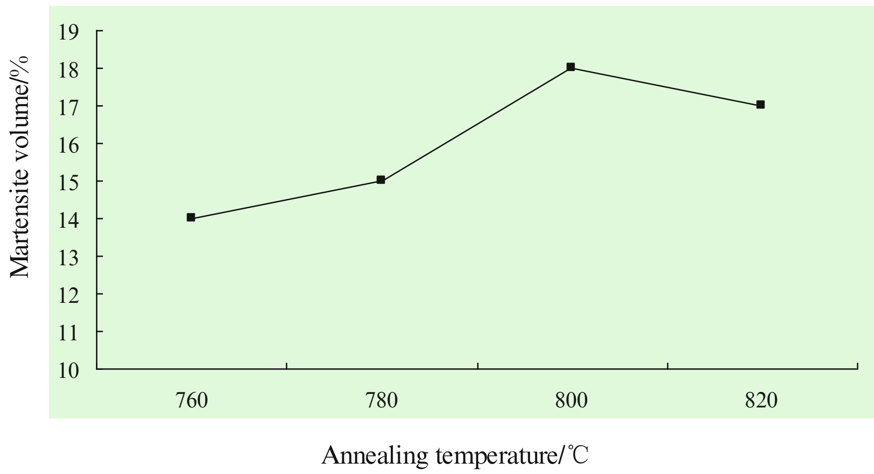


Fig.3 Effect of annealing temperatures on the volume fraction of martensite

Fig.4 (a) shows TEM photography of dual-phase for G3 specimen. The black insular martensite inlays the white ferrite, and the diameter is about 1um. Fig.4 (b) shows a martensite island. There are too many dislocations in ferrite nearby the martensite induced by phase transition. That's because the volume increase when phase changing and changing in the form of shearing. The high density dislocations at the interface of martensite and ferrite can move easily under external force. So the dual-phase presents the continuous yield.

When steel annealed at dual-phase zone, a great amount of carbide and nitride or some of them dissolve. And they can't precipitate when cooled. So when there are high density dislocations, the dual-phase steel presents the continuous yield and low yield strength.

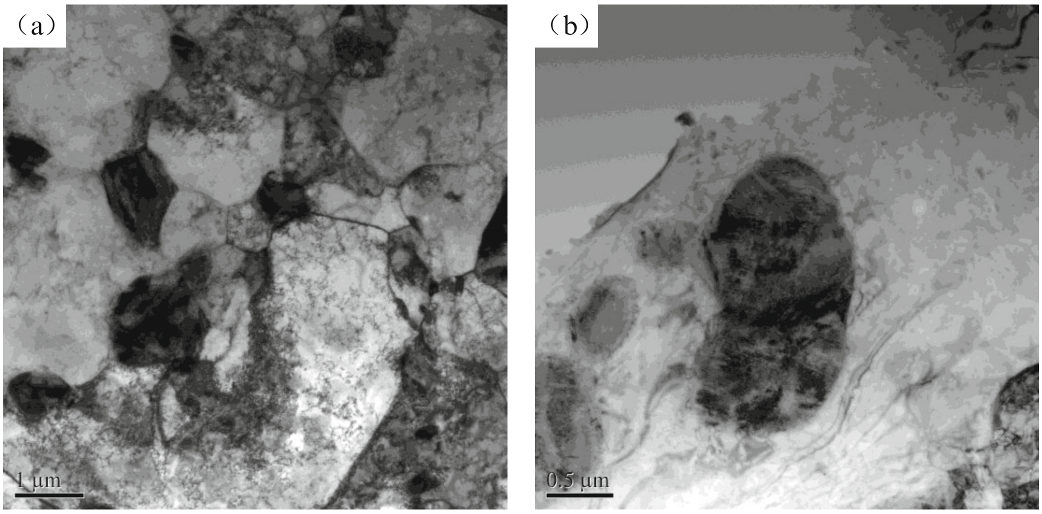


Fig.4 TEM micrographs of dual phase steel

Conclusions

Hot-dip galvanizing dual phase steel DP600 steel was produced by steel plant and experiments by simulating galvanizing thermal history. The tensile strength reached 658MPa, elongation 22% when annealed at 800℃. The grains of dual-phase steel will be finer and martensite volume will get more when annealing temperature is high. The black insular martensite inlays the white ferrite, and the diameter is about 1um from TEM observation. And there are too many dislocations in ferrite because of the martensite generation.

Reference

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