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THE APPLICATION OF Nb TO AUTOMOTIVE SHEET STEELS IN BAOSTEEL

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Abstract

The growth of China's automotive industry and demands for automotive sheet steels are briefly reviewed. The current status of development of automotive sheet steels (including hot-rolled, cold-rolled and coated steels), especially for Nb-bearing steel in Baosteel is introduced. The future of automotive sheets in Baosteel is forecasted. At the same time, the effects of Nb and Ti on mechanical properties of a newly developed HSLA590 high strength galvannealed (GA) sheet steel are described. Compared to Ti, Nb-bearing steel has a better stability of the mechanical properties and better galvannealability. The precipitation of the annealed steel is also discussed in this paper.

Introduction

Two important objectives of the automotive industry are the reduction of vehicle weight and the improvement of safety. Applying high strength steels with thinner gauge and zinc coating is the primary means used to reduce weight, improve safety and corrosion resistance.

Nb microalloying is frequently applied in the production of automotive sheet steels. For example, it has been applied widely in interstitial free steels (IF), high strength low alloy steels (HSLA) and advanced high strength steels (AHSS). Besides an increase of the tensile strength, it improves the ductile-to-brittle transition temperature (DBTT) and the galvannealability of IF steel [1]. Furthermore, it has been demonstrated that Nb-bearing steels are not sensitive to the process of hot rolling [2].

In this paper, results from a study examining the effect of Nb and Ti on mechanical properties of a newly developed HSLA590 high strength galvannealed (GA) sheet steels are presented. Compared with Ti, Nb-bearing steel shows a better stability of the mechanical properties and the galvannealability. Furthermore, the precipitation behavior of the annealed steel is discussed in this paper.

Characteristic of China's Automotive Sheet Steel Market

Since the early 1990s, the character of China's automotive industry has changed dramatically, with the infusion of foreign technology and large investments to modernize the industry. Figure 1 shows China annual sales of vehicles in recent years. Total vehicle sales grew from 0.51 million units in 1990 to about 5 million units in 2004, and it will become the world's third-largest auto manufacturer after the United States and Japan. Sedans accounting for 8 percent of the market in 1990 represent roughly 50 percent of the market in 2004, and will continue to be the fastest growing segment of the vehicle industry in the future. It is estimated that the total vehicle output will reach about 8 million units in 2010.

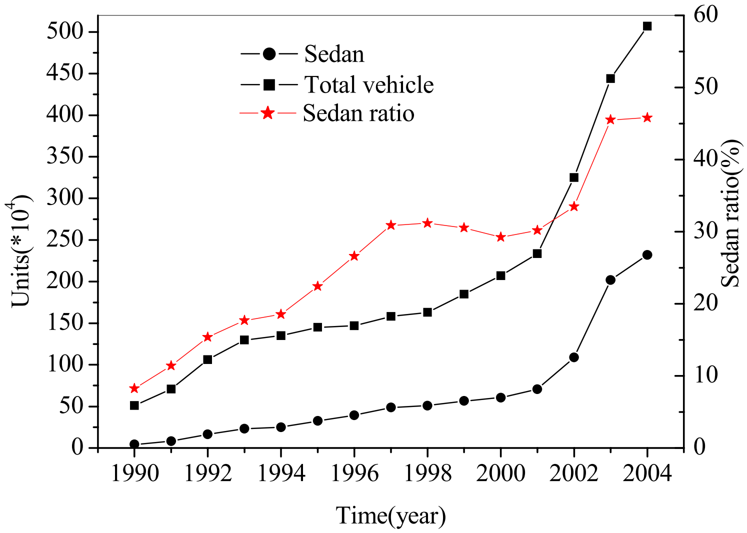


Figure 1. China annual sales of vehicles in recent years.

Along with the fast development of China's automotive industry and globalization of world economy, the China automotive market has become the stage for international competition. Many famous international automotive producers have entered China's car market by cooperating with domestic enterprises. More and more new models are introduced to China, the diversity in vehicle models leading to the diversity in standards, specifications and varieties of auto sheets. For example, the VW series of vehicles uses German standards, and covers hot dip galvanized, electro galvanized and various grades of high strength steel sheets. The Fukang series utilizes French standards and specifies mainly hot dip galvanized (GI) sheets. The Xiali series uses Japanese standards and mainly GA sheets. The Cherokee vehicles use American standards and both GI and GA sheets. The grades of automotive sheet steels used in China's market are shown in Table I.

Through the years of evolution of new advanced steels, uniform automotive sheet standards have been established in many countries, but not in China. This has made it difficult for steel plants to supply materials, especially when the demand for each type of steel is limited to small quantities. Compared with foreign markets, the demand for high strength and zinc-coated sheets in China's market is relatively low. However, this tendency will be changing rapidly.

Table I. Grades of automotive steels used in China's automotive market

Region	Outer panel	Inner panel and structure
American and European automakers	IF-EG BH180/220EG IS220/260EG	GI-IF HSLA340~420CR GI-DP600
Japanese automakers	IF-EG BH340GA HSSIF340~390CR	IF-CR C-Mn-CR HSSIF340~390CR HSLA440~590
China's automakers	IF-CR HSSIF340CR BH180CR	IF-CR Al-killed-CR

*Note: CR: Cold-rolled; GI: Galvanized; GA: Galvannealed; EG: Electro-Galvanized

Development of Nb-bearing Automotive Steel Sheets in BAOSTEEL

Baosteel is the largest automotive sheet steel manufacturer in China. Figure 2 shows the annual output of automotive sheet steels recently. The total output of automotive sheet steels grew from 0.6 million tons in 1996 to 1.8 million tons in 2004.

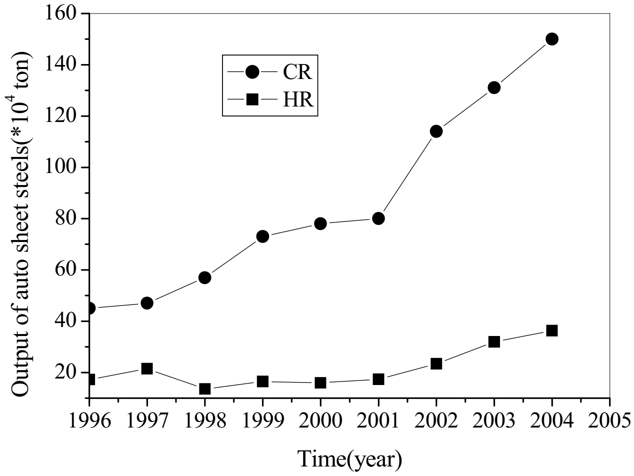


Figure 2. The annual output of automotive sheet steels recently in Baosteel

Table II. The main varieties of Nb-bearing sheet steels in Baosteel

Name	Grade	TS/MPa													
		>250	340	390	440	490	540	590	690	780	980	1180	1270	1370	1470
CR & EG	IF(DDQ~SEDDQ)	●	/	/	/	/	/	/	/	/	/	/	/	/	/
	HSS-IF	/	●	●	●	/	/	/	/	/	/	/	/	/	/
	BH	/	●	●	/	/	/	/	/	/	/	/	/	/	/
	HSLA	/	/	●	●	●	●	●	/	/	/	/	/	/	/
	DP	/	/	/	○	●	/	●	☆	●	/	/	/	/	/
	TRIP	/	/	/	/	/	/	●	☆	○	☆	/	/	/	/
	Mart	/	/	/	/	/	/	/	/	/	○	○	/	/	☆
GI & GA	IF(DDQ~SEDDQ)	●	/	/	/	/	/	/	/	/	/	/	/	/	/
	HSS-IF	/	●	●	●	/	/	/	/	/	/	/	/	/	/
	BH	/	●	●	/	/	/	/	/	/	/	/	/	/	/
	HSLA	/	/	●	●	●	●	●	/	/	/	/	/	/	/
	DP	/	/	/	○	●	/	●	☆	●	/	/	/	/	/
	TRIP	/	/	/	/	/	/	○	☆	☆	/	/	/	/	/
HR	HSLA	/	/	/	●	●	●	●	●	●	/	/	/	/	/
	DP	/	/	/	/	/	/	●	☆	○	/	/	/	/	/
	F+B	/	/	/	/	/	○	○	☆	☆	/	/	/	/	/
	CP	/	/	/	/	/	/	/	/	☆	●	/	/	/	/
	Mart	/	/	/	/	/	/	/	/	/	○	○	/	/	/

*Note: ● Commercial; ○ Under Development; ☆ To be developed

Besides the increased volume of automotive sheet steels, the variety has also increased, comprising hot-rolled, hot-rolled pickled, cold-rolled, hot dip galvanized (GI), galvannealed (GA), electrogalvanized (EG) and their post treated sheet steels over the tensile strength range from 250 MPa to 800 MPa. In these steels, Nb is often added to improve the properties. Table II shows the main varieties of Nb-bearing sheet steels in Baosteel. Among these different steel grades, there are two predominant types of steels with Nb addition. One type is galvanized IF steel and the other is hot-rolled HSLA steel. Figure 3 shows the annual output of IF steel sheet and the ratio of Nb-bearing IF steel sheet. The demand for Nb-added IF steel sheet having a share of about 20% is increasing rapidly.

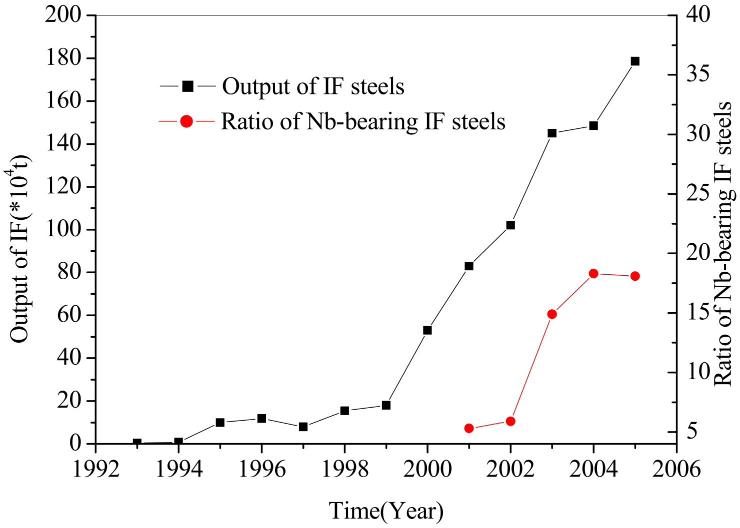


Figure 3. Annual output of IF sheet steels and the ratio of Nb-bearing IF sheet steels.

Experimental Procedures

The composition of the investigated HSLA590 steel is shown in Table III. It was melted in a medium frequency furnace in the laboratory. The ingots were forged to a thickness of 35 mm. The slabs were reheated to a temperature of 1250°C and hot rolled to a thickness of 2.6 mm. The finishing temperature was about 860°C. In order to simulate coiling, the hot rolled sheets were rapidly cooled to a temperature of 640°C and then slowly cooled in a furnace to room temperature. The thickness of annealed steel sheets finally obtained is 1.0 mm.

Table III. Chemical composition of the HSLA590 in wt.%.

No.	C	Si	Mn	P	S	Al	Nb	Ti	N
#1	0.10	0.02	1.64	0.005	0.004	0.026	0.057	0.035	0.0019
#2	0.09	0.2	1.73	0.008	0.005	0.032	0.045	0.002	0.0041

Annealing simulations

The annealing simulations were conducted in the laboratory with the Annealing Simulator (CCTAW-Y) on cold-rolled sheet. The heat-treatment conditions are shown in Figure 4. In order to study the effect of the soaking temperature on the mechanical properties, the temperature was varied from 780°C to 840°C and the soaking time was 60 seconds.

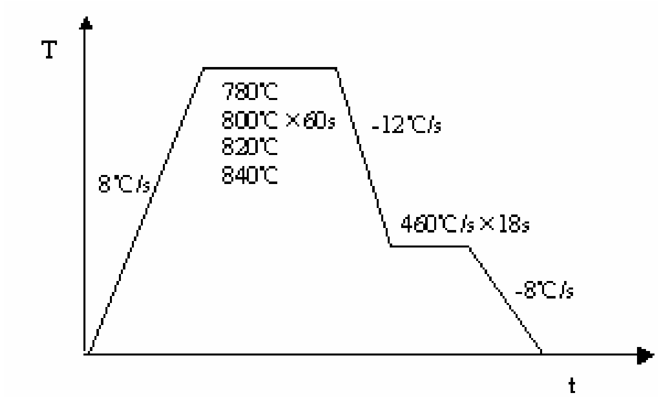
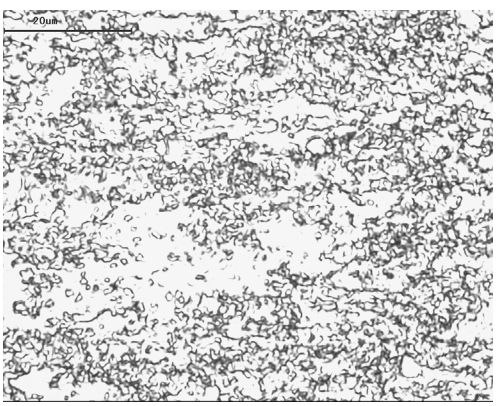


Figure 4. Schematic representation of the laboratory annealing cycle.

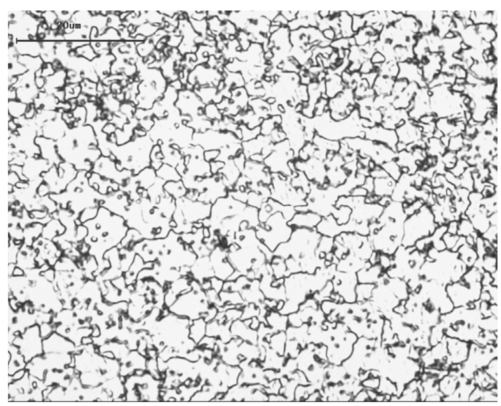
Mechanical properties were measured on an INSTRON-5581 tensile testing machine according to the JIS#5 specimen. The tensile specimens were machined with the tensile axis vertical to the rolling direction and were tested in the as-annealed condition. The microstructures were analyzed by standard optical microscopy; the samples were etched with Nital agent. The distribution of fine particles in the annealed specimens was observed by TEM using replicas.

Results and Discussions

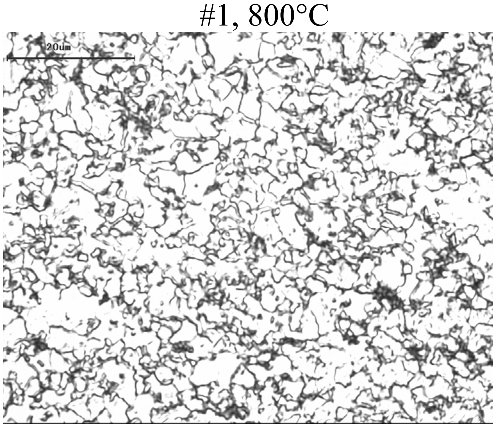
The influence of the soaking temperature on the microstructure of the investigated steel is shown in Figure 5. The microstructure is polygonal ferrite. With increasing annealing temperature the grain size remains at the same level for Nb-bearing steel. However, the grain grows for Nb+Ti co-added steel.



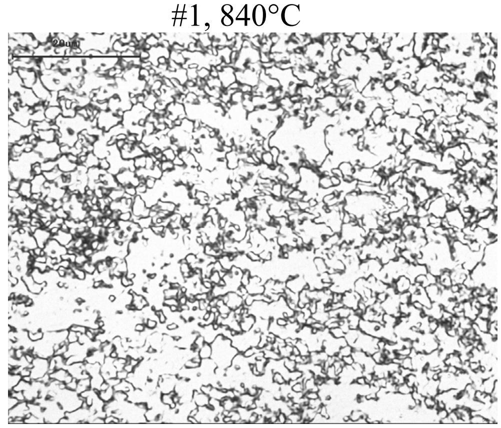
#1, 800°C



#1, 840°C



#2, 800°C



#2, 840°C

Figure 5. Influence of the soaking temperature on the microstructure.

Additional to the microstructure, the mechanical properties are shown as a function of soaking temperature in Figure 6. Tensile strength (TS) and yield strength (YS) decreased and elongation (EL) increased with the annealing temperature increasing from 780°C to 840°C. Compared to Nb+Ti co-added steel, Nb-bearing steel represented a higher TS×EL and a lower yield strength at the same annealing temperature.

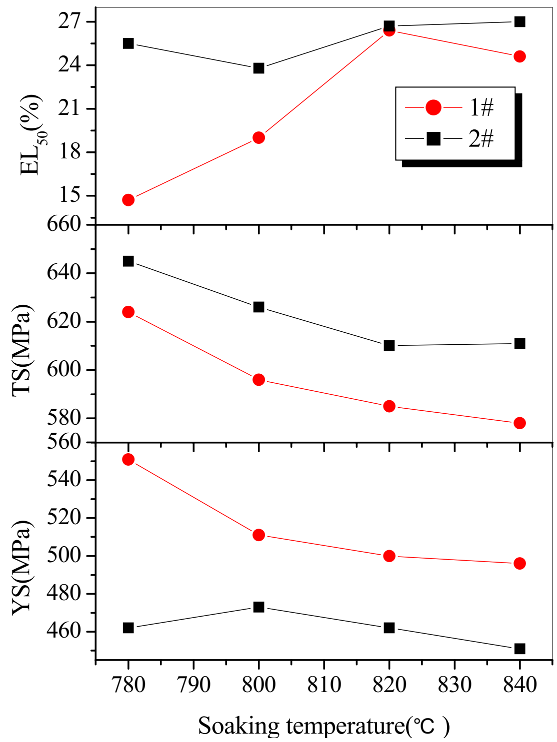
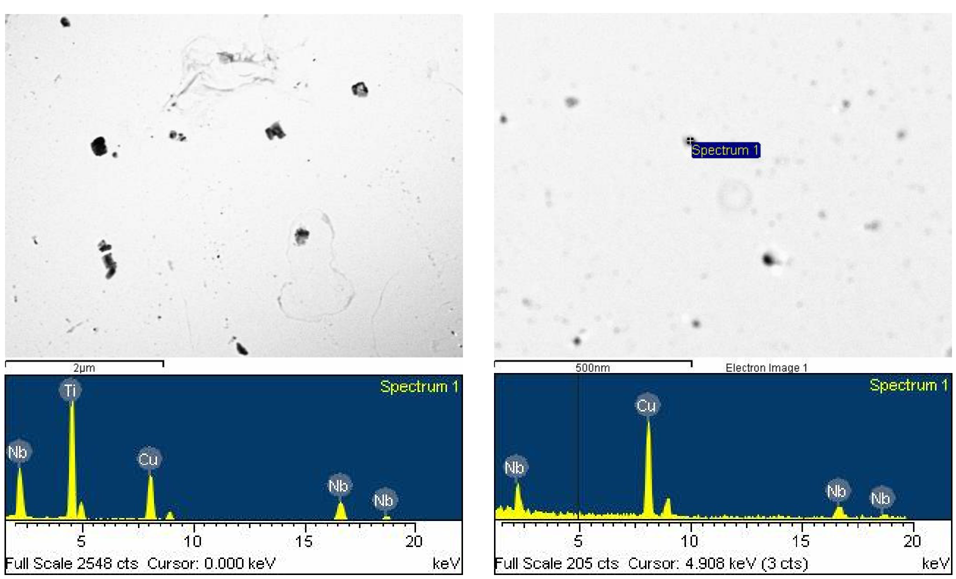


Figure 6. Influence of the soaking temperature on the mechanical properties.



1# 2#

Figure7. Influence of the composition on the behavior of precipitation (840°C).

Ti and Nb are the main precipitation-hardening elements. However, the effects of Ti+Nb and Nb on YS and TS are different. TS increases with 0.035% Ti addition, while YS and EL decrease, see Figure 6. Figure 7 shows the precipitation behavior of #1 and #2 steel annealed at 840°C. The size of precipitation in Nb+Ti co-added steel is larger than that in Nb-bearing steel, which may be the main reason for the TS being higher in the Nb-bearing steel.

Conclusions

Based on this study, some conclusions can be drawn:

1) With the annealing temperature increasing from 800°C to 840°C, the grain size is at the same level for Nb-bearing steel. On the contrary, in Nb+Ti co-added steel, the grain size is coarsening.

2) Tensile strength and yield strength decreased and elongation increased with the annealing temperature increasing from 780°C to 840°C. Compared to Nb+Ti co-added steel, Nb-bearing steel represented a higher TS×EL and a lower yield strength at the same annealing temperature.

3) The size of precipitation in Nb+Ti co-added steel is larger than that in Nb-bearing steel, which may be the main reason for the TS being higher in the Nb-bearing steel.

References

1. Anthony J.DeArdo, NIOBIUM IN STEELS AND ALLOYS (Beijing, 20 Years of Cooperation CISRI Chinese Steel Industry CBMM, 1999), 127-140.
2. Klaus Hulka, NIOBIUM IN STEELS AND ALLOYS (Beijing, 20 Years of Cooperation CISRI Chinese Steel Industry CBMM, 1999), 83-110.