

Development of 780MPa grade gal annealed dual phase steel sheets for automobile

Yinghua Jiang^{1,2,*}, Chunqian Xie^{1,2} and Shuang Kuang^{1,2}

¹Shougang Research Institute of Technology, Beijing 100043, China

²Beijing key Laboratory of Green Recyclable Process for Iron & steel Production Technology, Beijing 100043, China.

*Corresponding author e-mail:yinghuajiang@163.com

Abstract. As the weight reduction of automotive body and crash safety become much more important factors, in an effort to satisfy these requirements, Shougang has developed 780MPa grade galvanized dual phase steel sheet. Steel chemistry with low C and low Si was designed for good zinc wettability and spot weldability. And some of elements were added to improve the hole expansibility and work hardening capacity of steel as these effectively refine the microstructure and introduce retained austenite. Newly developed 780MPa grade galvanized dual phase steels have a high yield strength and a good hole expansibility.

1. Introduction

DP steels, with their hard phase islands (martensite) embedded in a soft phase (ferrite), have unique properties such as high strength, low yield-to-tensile strength ratio, high initial work hardening rate, bake hardenability, and no room temperature aging effects [1-3]. Therefore DP steels were widely applied to great numbers of automotive parts. However, stamping of DP steels presents new challenges because under certain stretch flanging conditions, DP steels may fail through fracture during stamping [4-5]. The inhomogeneous microstructure of soft ferrite and hard martensite in combination with local straining is inherent to these problems. However, forming behavior can be much improved by microstructural refinement and homogenization of the phases as well as modification of hardness contrasts [6].

Recently, the automotive industry has been required to ensure the corrosion resistance of automotive component [7]. In order to meet this demand, hot-dip galvanized DP steel was developed. However, compared with a continuous annealing line (CAL), in a continuous galvanizing line (CGL), the cooling rate was limited during galvanizing and gal annealing treatment, it is difficult to obtain DP microstructure.

Hence, production of hot-dip galvanized DP steels with high whole expansibility through the control of chemical composition and manufacturing conditions is important. In this study, to obtain 780MPa grade hot-dip galvanized DP steels, the effects of chemical composition and heat treatment condition on the mechanical properties and microstructure of the material were investigated. Based on laboratory investigation, 780MPa grade hot-dip galvanized DP steels were produced by a commercial CGL in Shougang.



2. Experimental procedure

In the present study, the hot-dip gal annealed DP steels were produced using a laboratory annealing simulator. DP steels with high strength usually contain several kinds of strengthening elements such as Si, Mn and so on, but these strengthening elements also deteriorate the galvanizing property due to the surface oxides formed during annealing process [8]. So the low Si-low C materials are expected to improve coat ability and spot weld ability. The low-C grades needed to add appropriate the alloying elements (Cr, Mo, B etc.) to improve hardenability of sheet to obtain DP microstructure. And some of elements (Nb, Ti, and Al.) were added to improve the whole expansibility and work hardening capacity of steel as these effectively refine the microstructure and introduce retained austenite. The chemical compositions of the steels used for this study was provided in Table 1. Experimental ingots made about 50kg in laboratory by vacuum induction furnace. They were homogenized at 1200°C for 1hours and then hot rolled to 3mm hot band. Finishing temperatures were kept above 870°C and coiling temperatures were kept at 670°C, then air cooled to ambient temperature. Then, steel sheets are cold rolled to 1.2mm thick. The heat treatment cycle fully simulated the industrial CGL. The coating was gal annealed at the annealing temperatures ranging from 500 to 580°C. In order to distinguish each phase (marten site, ferrite etc.) the microstructure of steels were investigated after etching using Nital and Le Pera solution by optical microscope. Structural characterization was carried out transmission electron microscopy (TEM). The chemical composition of precipitates was determined by energy-dispersive X-ray (TEM-EDS). The mechanical properties of the steels were examined using tensile test machine. Whole expansion testing was also carried out. The whole expansibility of steels was evaluated by whole expansion ratio where the whole expansion ratio is defined as:

$$\lambda = \frac{d_f - d_0}{d_0} \times 100\% \quad (1)$$

Where d_0 is the initial whole diameter and d_f the hole diameter on cracking.

Table 1 The chemical compositions of the steels used in this study (wt %)

C	Al	Si	Mn	Cr+Mo	B	Ti+Nb	P	S	Pcm
0.08-0.1	0.5-1.0	<0.3	1.9-2.1	<0.5	0.0008 -0.0015	<0.03	<0.01	<0.01	0.223

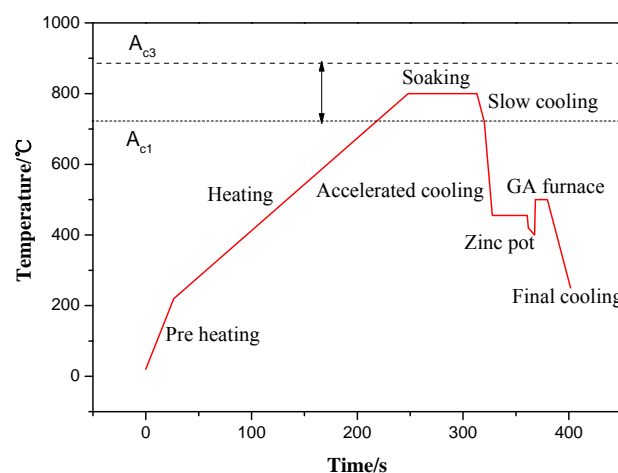


Figure 1. Heat cycle for advance high strength steel sheets

3. Results and discussions

Figure 2(a) shows the effects of annealing temperature on the mechanical properties. It is revealed that both the yield strength and the tensile strength decrease with an increase in the annealing temperature, while elongation increases with an increase in the annealing temperature. Figure 2(b) shows the effects of gal annealing temperature on the mechanical properties. It is revealed that both the tensile strength and elongation decrease with an increase in gal annealing the temperature, while the yield strength increases with an increase in the gal annealing temperature. When high gal annealing temperature the pearlite is formed, this corresponded to an increase in yield strength and a decrease in tensile strength and elongation. It can be concluded that the optimum mechanical properties are obtained when the annealing temperature is 800 °C and the gal annealing temperature is 520 °C.

The optical micrograph after the industrial CGL heat treatment is shown in Figure 3a. This microstructure (Figure 3a) consists of mainly ferrite and MA Island (marten site + austenite). The microstructural characteristics, a refined grain as well as homogeneous phase distribution can be observed. Figure 3b shows a TEM micrograph of retained austenite. The TEM micrograph of trial steel is shown in Figure 4. Figure 4 shows well dispersed particles of a few ten nanometers, which was identified as TiNbC composite precipitates due to their chemical composition. A small addition of Nb and Ti are the most effective in achieving refinement and homogenization microstructure.

The production of 780 MPa grade GA DP trial steel sheets was carried out based on a laboratory investigation. Figure 5 shows SEM images obtained from the surface of the steel sheets and a cross section of the coating layer. In zinc coating, the coating weight was 45 g/m² per side and the iron content ranged from 10.3 to 11.1%.

Figure 6 shows the typical mechanical properties of trial steel produced by Shougang and original steel. The trial steel has excellent mechanical properties compare with original steel. The excellent mechanical properties of the trial steel come from the optimized microstructure. The introduction of retained austenite results in an increased elongation and n-value. And the microstructural refinement in combination with homogenization of the individual phases led to an increased λ -value.

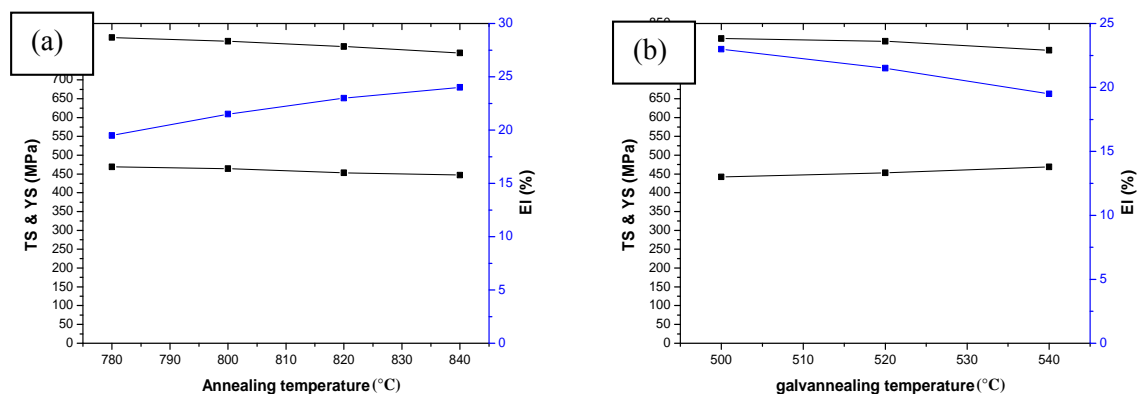


Figure 2. Effects of a) annealing temperature and b) gal annealing temperature on mechanical properties of the trial steel

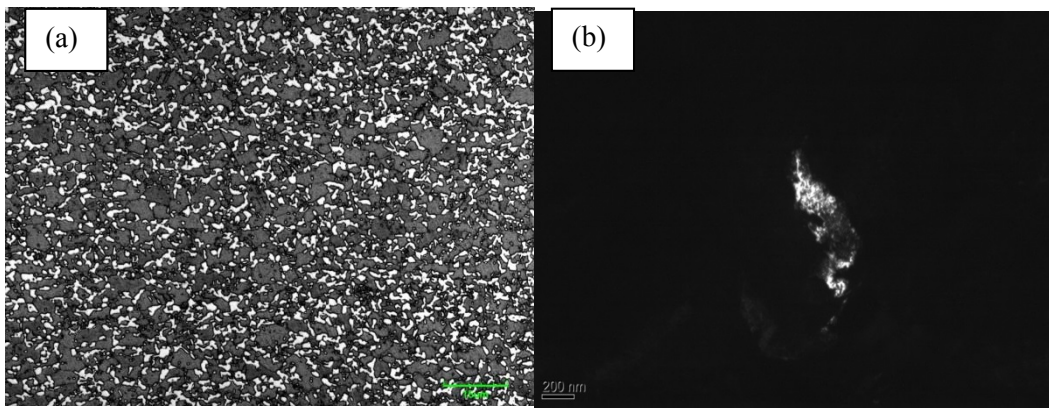


Figure 3. a) The optical micrographs and b) dark field TEM micrographs of retained austenite for the trial steel

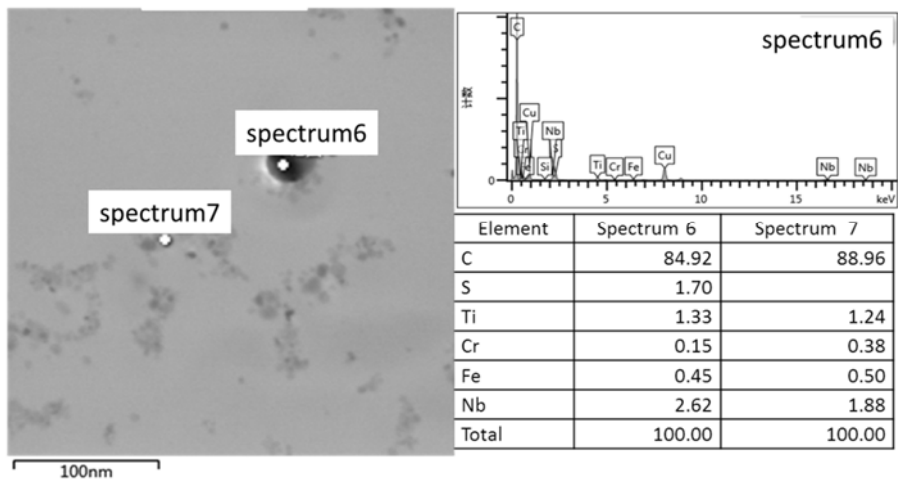


Figure 4. TEM micrograph of precipitates in trial steel

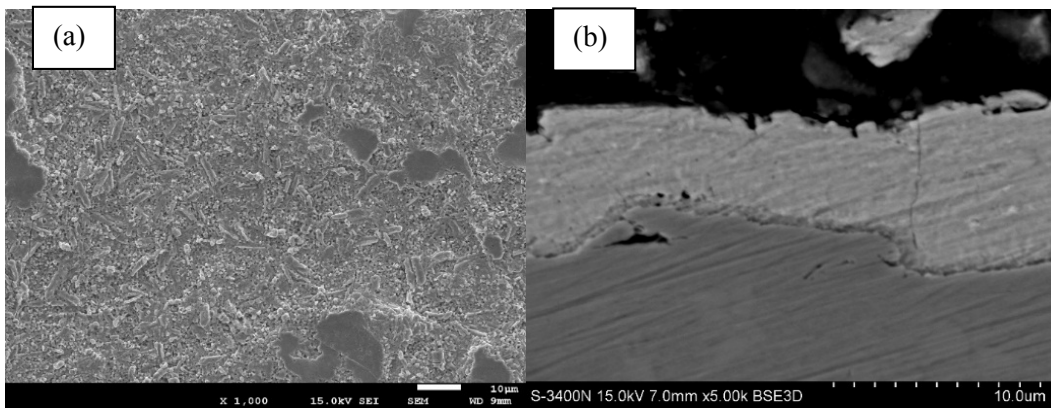


Figure 5. SEM images of trial steel a) surface appearance, and b) cross-section

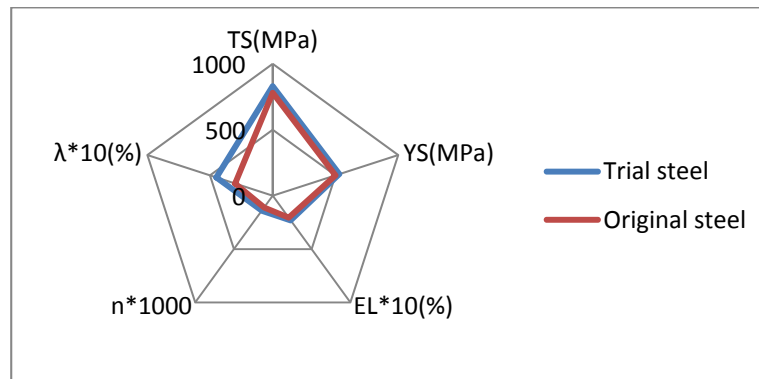


Figure 6. Typical mechanical property of the trial steel and original steel

4. Conclusion

High λ type 780MPa grade gal annealed dual phase steel sheet with improved stretch-flange ability was developed. An annealing temperature of 800°C and gal annealing temperature of 520°C are recommended for the optimized mechanical properties. Further Nb and Ti addition will improve the whole expansion performance by refining and homogenizing the microstructure.

References

- [1] LUO Juan-juan, SHI Wen, HUANG Qun-Iei and LI Lin, Heat Treatment of Cold-Rolled Low-Carbon Si-Mn Dual Phase Steels, *Journal of Iron and Steel Research. International*, 17(2010) 54-58.
- [2] P. Movahed, S. Kolahgar, S.P.H. Marashi, M. Pouranvari and N. Parvin, The effect of intercritical heat treatment temperature on the tensile properties and work hardening behavior of ferrite–martensite dual phase steel sheets, *Materials Science and Engineering A*, 518(2009) 1-6.
- [3] Manabu TAKAHASHI, Development of High Strength Steels for Automobiles, *NIPPON STEEL TECHNICAL REPORT*, 88(2003) 2-7.
- [4] Le-yu Zhou, Dan Zhang, and Ya-zheng Liu, Influence of silicon on the microstructures, mechanical properties and stretch-flangeability of dual phase steels, *International Journal of Minerals, Metallurgy and Materials*, 21(2014) 755-764.
- [5] J. Lee, S.J. Lee, and B.C. De Cooman, Effect of micro-alloying elements on the stretch-flangeability of dual phase steel, *Mater. Sci. Eng. A*, 536(2012) 231-238.
- [6] Kyohei KAMIBAYASHI, Yutaka TANABE, Yoshito TAKEMOTO, Ichirou SHIMIZU and Takehide SENUMA, Influence of Ti and Nb on the Strength–Ductility–Hole Expansion Ratio Balance of Hot-rolled Low-carbon High-strength Steel Sheets, *ISIJ International*, 52(2012) 151-157.
- [7] Kazunori Osawa, Yoshitsugu Suzuki, Shungo Tanaka, TS590~980 MPa Grade Low-Carbon Equivalent Type Galvannealed Sheet Steels with Superior Spot-Weldability, *KAWASAKI STEEL TECHNICAL REPORT*, 48(2003) 9-16.
- [8] Yusuke FUSHIWAKI, Yasunobu NAGATAKI, Hideki NAGANO, Wataru TANIMOTO and Yoshiharu SUGIMOTO, Influence of Fe Oxidation on Selective Oxidation Behavior of Si and Mn Added in High Strength Sheet Steel, *ISIJ International*, 54 (2014) 664-670.