The Microstructure and Properties of Vanadium-Bearing DP980 Steels Processed with Continuous Galvanizing Line Simulations

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Abstract:A study is being conducted of additions of the microalloying elements Nb, V and V-N to a low carbon, high-strength (980 grade) Dual-Phase steel that was processed using a CGL simulation. In this study, compositions with a common base but containing various additions of V or Nb with or without high N were designed and subjected to Gleeble simulations of different galvanizing(GI), galvannealing(GA) and super cooling processing. These experiments were supplemented with additional heat treatments performed using a quartz filament furnace. The results revealed that the phase balance (martensite-bainite-ferrite) was strongly influenced by the different microalloying additions, while the strengths of each phase were somewhat less affected. UTS levels of 1100MPa, along with good levels of ductility and work hardening, were measured in steels containing less than 0.1%C and 1.75%Mn. The results of this program will be presented and discussed.

Key words: Microalloyed dual-phase steels, High strength, Ductility, Work hardening, n-values, Yield/Tensile ration, Intercritical annealing, Galvanizing, Galvannealing, CG Lines, Simulations

Since most forming operations in automobiles involve plane strain bending or stretch- forming, the ideal steels must have moderate yield strength to improve die life, and good work hardening, as measured by the YS/UTS ratio or instantaneous "n values" [1,2]. High work hardening is important in both forming and possibly subsequent crumble-zone stability during crashing. In addition, candidate steels must also have good sheared edge ductility and an acceptable bake hardening response, if painted.

The modern dual-phase steels (DP) satisfy these requirements.Today, DP590 and DP780 are commercial realities, while DP980 and DP1180 are still being investigated[3]. The goal of this paper is to describe recent results from a continuing research program that is investigating DP steels at the 980 and 1180 MPa UTS level that have been microalloyed with Nb, V and V-N and have been processed using a CGL simulation on a Gleeble 3500.

This paper describes research that has been conducted on aluminum killed low carbon(0.1%) steels containing Mn, Cr, and Mo.In addition, the steels were microalloyed with Nb, Nb+V or Nb+V+N. After final CGL processing, these steels exhibited UTS values between 900 and 1100 MPa, and total elongations (corrected for sub-sized gauge length) between 8% and 17%. Some preliminary microstructural observations and processing-microstructure-property relations will be presented, described and discussed below.

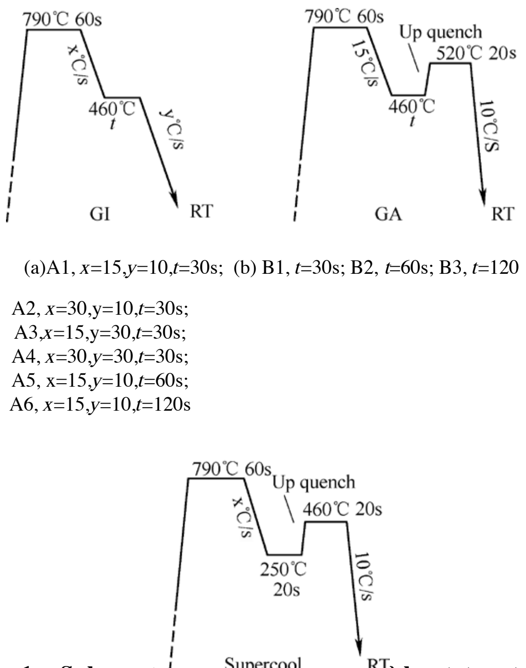
1 Experimental Procedure

The compositions of the 45kg laboratory vacuum-melted ingots are shown in Table 1. These ingots were reheated to 1200℃ and hot rolled to 3mm in several passes, finishing at 920℃.They were then water sprayed cooled at 10~15℃/s to the coiling temperature of 550℃. After coiling and cleaning, the hot band was cold rolled about 60% to 1.2mm sheet. Following cold rolling, the sheets were sectioned for the Gleeble simulation of the CGL processing. This processing is shown in Fig.1.

The microstructural analysis of all the intercritically annealed specimens was conducted using standard optical and electron optical techniques (OM, SEM and TEM). The SEM metallography was performed on a Philips XL-30 FEG-SEM microscope and the TEM was performed on either a JEOL-200CX or a 2100F microscope, both operated at 200kV. The composition of the carbides was determined by using an EDS-Oxford system attached to the TEM. The retained austenite was measured with a LakeShore® magnetometer.

Table 1 Chemical Composition of V-DPTR Steels（%）

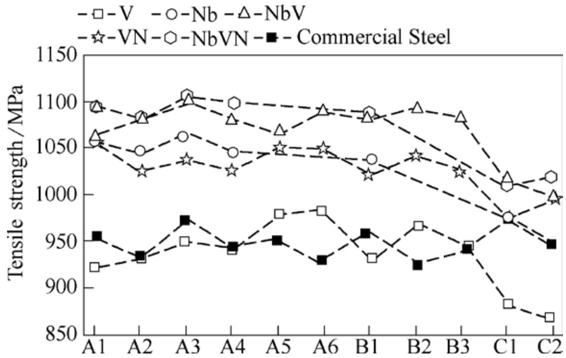
Element/steel	DP_V	DP_VN	DP_Nb	DP_NbV	DP_NbVN
V	0.06	0.06	0.00	0.06	0.06
Nb	0.00	0.00	0.025	0.025	0.025
N /ppm	0.006	0.014	0.006	0.006	0.014
Others: 0.10C, 1.75Mn, 0.40Si, 0.01P, 0.025Al, 0.50Cr, 0.30Mo, 0.003S					



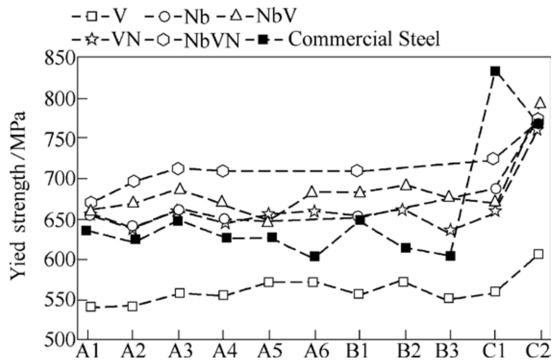
(a)A1, x=15,y=10,t=30s; (b) B1, t=30s; B2, t=60s; B3, t=120

A2, x=30,y=10,t=30s;
A3,x=15,y=30,t=30s;
A4, x=30,y=30,t=30s;
A5, x=15,y=10,t=60s;
A6, x=15,y=10,t=120s

Fig. 1 Schematic representation of heat-treatment schedules for Gleeble processes



(a)



(b)

Fig. 2 Tensile strength and 0.2 % yield strength of DP steels in this work, and the corresponding values of commercial DP steels are also included

2 Results and Discussion

The mechanical properties resulting from the seven processing routes are shown in Figs. 2(YS and UTS), 3(% uniform and % total elongations), and 4(YS/UTS and n values).

The Nb-V-N and Nb-V steels showed the highest UTS, but the lowest n –values. The Nb and V-N steels showed the next highest UTS levels and improved n-values. The V steel and the non-microalloyed commercial steel have the lowest strength, but the highest elongations.

A comparison of the tensile properties found in this current study with those from the literature is shown in Fig.5 and Fig.6[4].

It is apparent from Fig.5 that the steels are located above the base line for strength –vs–% martensite in the final structure. However, their ductility values lie somewhat below the C-Mn trend line, Fig.6. Fig.5 helps explain the low strength found in the DPV steel, i.e., the amount of martensite in this steel is abnormally low given the carbon content and annealing temperature.

To help explain the low amount of martensite found in the DPV steel, the martensite was determined in intercritically annealed and immediately water quenched specimens. These values for several steels are shown in Table 2. It is apparent that the formation of austenite during the ICA is retarded in the DPV steel when compared with the others.

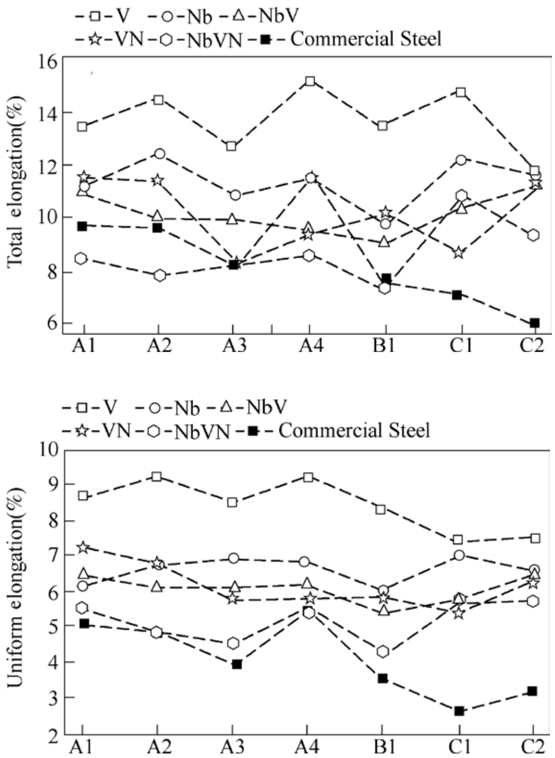


Fig. 3 Total elongation in 2 inch and uniform elongation in 2 inch of DP steels in this work, and the corresponding values of commercial DP steels are also included

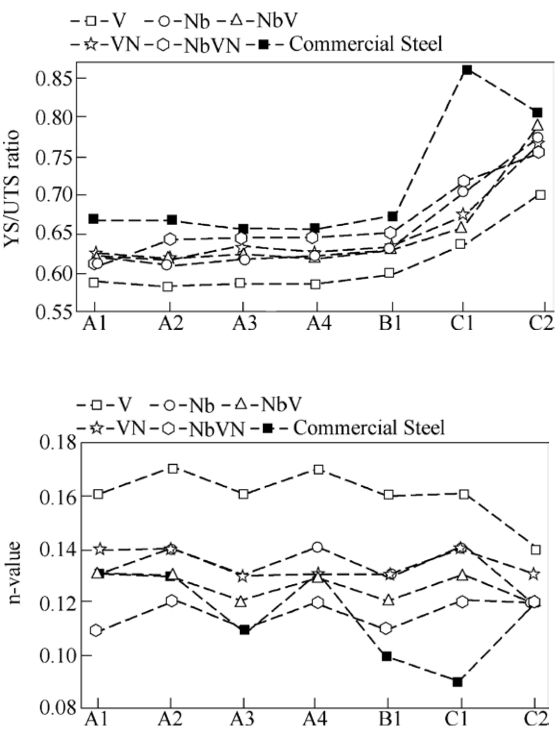


Fig. 4 The yield strength to tensile strength ratio, strain hardening exponent n (in the range 4% to 6%) of DP steels in this work, and the corresponding values of commercial DP steels are also included

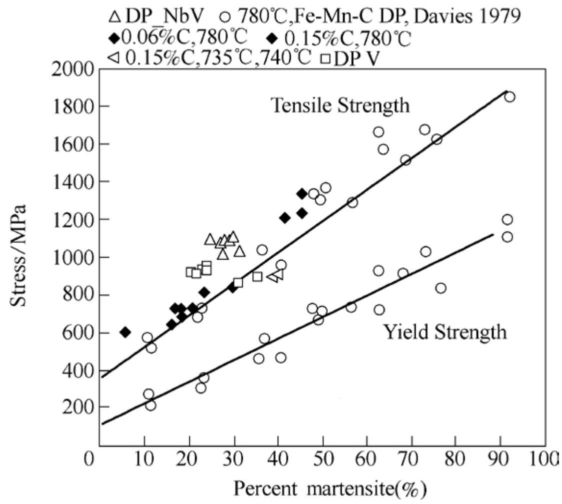


Fig. 5 Comparison of MA volume fraction vs UTS with the corresponding values obtained by Davies[4]

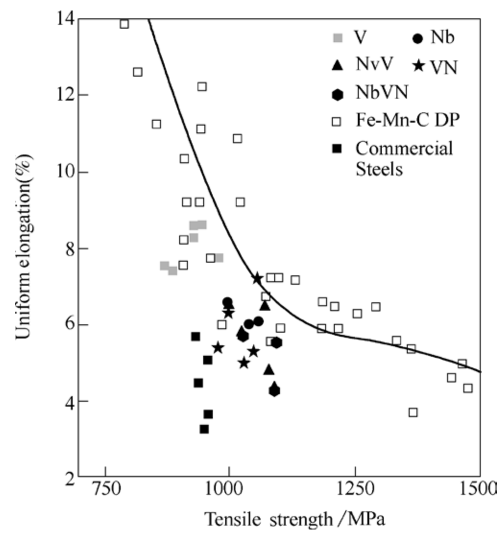


Fig. 6 Comparison of UTS vs UE with the corresponding values obtained by Davies[4]. The values of commercial steels are also included

Table 2 The volume fraction of martensite in the intercritically annealed and immediately water quenched specimens

	DP_V	DP_Nb	DP_VN	DP_NbV
780℃, 1min, WQ	18±1	51±2	34±2	47±2

Since retained austenite is thought to help improve tensile elongation and n-values, it was measured in DPNbV steel. The volume % retained austenite was consistently near 2%~5% for the GI(A1-A4) and GA(B) processing, but it reached higher levels of around 8% in the super cooled processing(C1 and C2), as shown in Fig.7. These data illustrated in Fig.7 show the positive influence of retained austenite. Combining the strength data shown in Fig.2, the YS/UTS results presented in Fig.4, and the retained austenite measurements given in Fig.7, together describe a steel with a high YS/UTS ratio at high strength levels with good ductility.

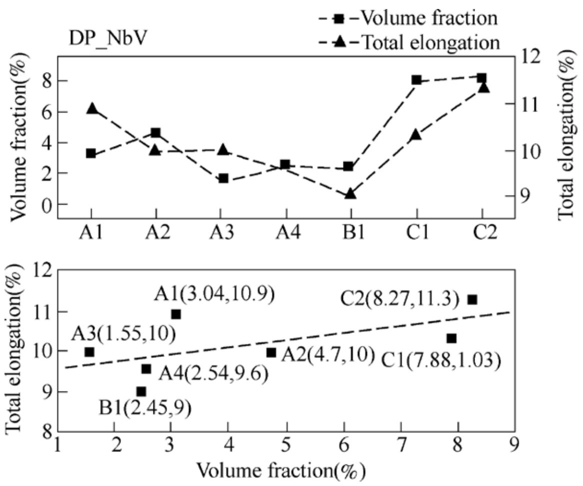


Fig.7 The relationship between the volume fractions of retained austenite obtained by magnetometry and the total elongations of the DPNbV steels

3 Summary and Conclusions

The results of this study have shown that the nature of the microalloying addition can influence the final microstructure and properties. The properties fell into three bands: (i) Highest strength-low ductility (DPNbVN and DPNbV steels);(ii)Jintermediate strength and ductility(DPVN and DPNb steels); (iii)Lowest strength-highest ductility(DPV and commercial steels).

The low strength of the DPV steel is at least partially caused by the low amount of austenite found after the intercritical anneal.

The super cooling treatments C1 and C2 (790~250 ~460℃) indicate it is possible to have high levels of strength, YS/UTS ratio and ductility at the same time.

Acknowledgements:

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