Effect of Microalloying and Quenching Process on Cold Bending Properties of 38MnB5 Hot Forming Steel

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Abstract. Referring to the standard "VDA 238-100 Plate Bending Test for Sheet Metal" and GB/T 228.1-2010 to study the ultimate tip cold bending and mechanical properties of ultra-high strength hot forming steel, the results show that the tensile strength of Nb+Ti composite microalloyed hot forming steel increases significantly with the increase of cooling rate, and the ultimate tip cold bending angle does not change much. On the contrary, the effect of cooling rates on the mechanical properties of Nb+Ti+V composite microalloyed steel is small, because the addition of V provides sufficient hardenability to obtain a fully martensitic microstructure at lower cooling rates. At higher cooling rates or larger ultimate tip cold bending angles, the addition of V improves the mechanical properties and cold bending properties of the hot forming steels more significantly.

Keywords: 38MnB5 hot forming steel · Microalloying · Quenching cooling rates · Mechanical properties · Cold bending properties

1 Introduction

As the problem of global warming becomes more and more serious, countries around the world are gradually demanding a reduction in greenhouse gas emissions, of which automobile exhaust emission is a very important part, since the concept of "automotive lightweighting" is proposed, that is, through lightweight materials, lightweight structural design and process optimization to reduce car body weight. Ultra-high strength steel utilizes solid solution strengthening, precipitation strengthening, grain refinement, dislocation strengthening and phase transformation strengthening (martensitic phase transformation) to achieve a significant increase in strength, replacing the traditional low strength steel in the car body. However, the increase in strength will lead to a reduction in the plasticity and formability of the steel, and it is tough to produce specific shaped parts through the traditional cold forming process, so hot forming technology is used to process ultra-high strength steel sheets. In view of these drawbacks, this study intends to optimize the current hot forming steel composition system by micro-alloying Nb, V and Ti to improve the cold bending properties of hot forming steel.

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Table 1. Chemical composition of test steel (%, mass fraction).

	C	Si	Mn	B	Cr	Ti	Nb	V
1#	0.38	0.24	1.28	0.005	0.25	0.022	0.035	0.03
2#	0.38	0.25	1.33	0.006	0.28	0.023	0.033	—

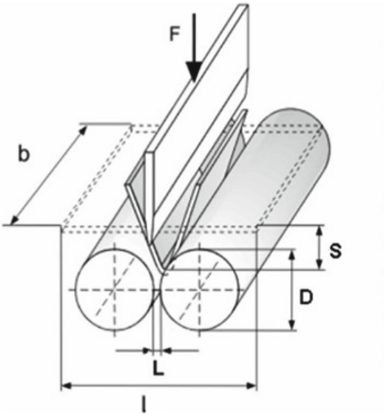

Fig. 1. Schematic diagram of bending device.

2 Material and Experimental

The tested hot forming steels were smelted in a laboratory 50 kg vacuum induction furnace and vacuum cast into ingots with the chemical composition shown in Table 1, the ingots were forged into 35 mm thick cast billets, after which they were hot rolled to 5 mm, held at 610 °C for 2 h air-cooled to simulate coiling, then they were pickled and cold rolled with a reduction ratio of 75%.

A50 tensile specimens and 60 mm × 60 mm × 1.2 mm ultimate tip cold bending specimens were cut by using wire cutting machine, simulated cover annealing process, the specimens were heated to 680 °C, holding 4 h after air cooling, followed by a simulated hot stamping die quenching process, the specific process is: 10 °C/s heating to 930 °C, holding 10 min, following 30 °C/s and 50 °C/s cooling rates to room temperature. Taking advantage of electronic universal testing machine CMT5605 for mechanical properties testing, with reference to the standard "VDA 238-100 plate bending test of metal plates" on the above specimens for the ultimate tip cold bending test. The bending device shown in schematic Fig. 1.

3 Results and Discussion

Figure 2 shows the stress-strain curves of 1# and 2# steel after quenching in simulated hot stamping dies at different cooling rates. Both steels exhibit continuous yielding behavior, and the effect of cooling rates on the mechanical properties of 1# steel is not

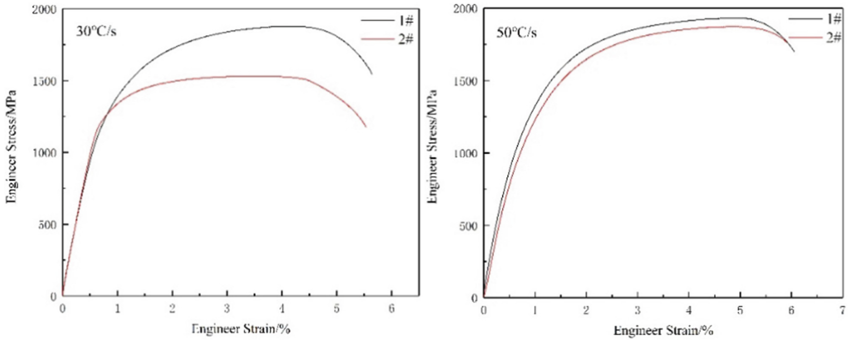

Fig. 2. Stress-strain curves of 1# and 2# steel after simulated hot stamping dies quenching treatment.

Table 2. Mechanical properties of 1# and 2# steel after simulated hot stamping dies quenching treatment.

Cooling rates °C/s	Sample	Yield Strength/MPa	Tensile Strength/MPa	Uniform Elongation/%	Total Elongation/%
30	1#	1280	1880	4.1	5.7
	2#	1270	1532	3.6	5.5
50	1#	1130	1933	4.9	6.1
	2#	1100	1873	4.8	5.9

significant, indicating that a cold speed of 30 °C/s is sufficient to obtain a fully martensitic microstructure. For 2# steel, when the cooling rate reaches 50 °C/s, its tensile strength and elongation are significantly increased compared to 30 °C/s, but the yield strength is slightly reduced, indicating that the cooling rate of 30 °C/s cannot obtain full martensite, and the corresponding elongation is also lower.

As shown in Table 2, the tensile strength of 2# steel without the addition of V is lower than that of 1# steel at different cooling rates, but the difference in yield strength and elongation is not significant, which indicates that V enhances the strengthening effect of Nb and Ti microalloying, and this part of the strengthening increment comes from the precipitation strengthening generated from the composite carbon-nitride precipitation of V, Nb and Ti by pinning dislocations.

Figure 3 shows the ultimate tip cold bending angles of 1# and 2# steel after simulated hot stamping die quenching treatment under different cooling rates conditions. The ultimate tip cold bending angle of 1# steel increases with the increased cooling rates, but the ultimate tip cold bending angle of 2# steel is almost not affected by the cooling rates, and the ultimate tip cold bending angle of 1# steel is higher than that of 2# steel, indicating that the addition of V motivates to improve the cold bending performance of hot forming steel.

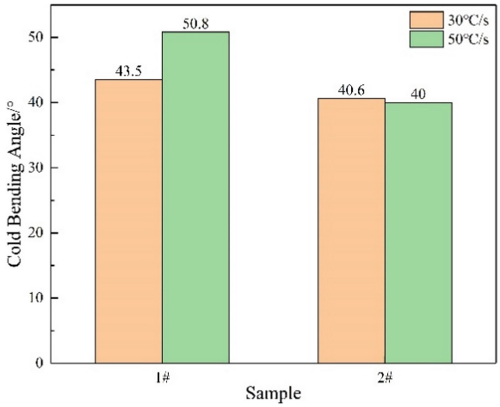

Fig. 3. Bar graph of the ultimate tip cold bending Angle of 1# and 2# steel after simulated hot stamping dies quenching treatment.

4 Conclusion

(1) The heating temperature of 930 °C and holding time of 10 min was a reasonable parameter to simulate the quenching temperature of hot forming steel in this study, the cooling rates had less effect on the mechanical properties of 1# steel, the addition of V provided sufficient hardenability, however 2# steel get full martensite microstructure at 50 °C/s, regardless of the cooling rates, the tensile strength of 1# steel was higher than that of 2# steel.

(2) The ultimate tip cold bending angles of 1# steel was influenced by the cooling rates, while the addition of V made the ultimate tip cold bending angles of 1# higher than that of 2# steel irrespective of the cooling rates, Nb, V, Ti composite microalloying is conducive to improving the cold bending properties of hot forming steel.

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