Factors Affecting Intrusion Resistance of Hot Stamping Steel

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Abstract. In this paper, we studied the effect of decarburization layer thickness and carbon content on the ultimate cold bending angle of the hot stamping steels. The ultimate cold bending angle of hot stamping steel with 0.23 (wt. pct) carbon content and 0.35 (wt. pct) carbon content is compared. With the increase of carbon content, the ultimate cold bending angle decreases from 66.1° to 40.8°. The appearance of a completely decarburized layer in the microstructure will significantly increase the ultimate cold bending angle, from 66.1° to 77.4°. It can be found that carbon content is key factor affecting the ultimate cold bending angle of hot stamping steels, the thickness of the decarburized layer is another key factor affecting the ultimate cold bending angle of the hot stamping steels.

Keywords: Hot stamping steel · Decarburization layer · Carbon content · Ultimate cold bending angle

1 Introduction

As people pay more attention on the vehicle weight reduction and safety, more and more ultra strong sheets have been used on the automobile body [1, 2]. However, when the ultimate tensile strength exceeds 1000 MPa, cold forming faces problems such as difficult forming and springback [3]. The hot stamping process can obtain parts with martensite, and the ultimate tensile strength is greater than 1500 MPa, the high strength ensures the safety of personnel [4].

The ultimate cold bending performance affects the intrusion resistance and safety performance of hot stamping parts. Generally, the ultimate cold bending angle is required to be greater than 60° [5, 6]. In this paper, we study the effect of decarburization layer thickness and carbon content on the ultimate cold bending angle of the hot stamping steel.

Y. Zhang and M. Ma (Eds.): ICHSU 2022, AHMST 2, pp. 48–52, 2023.
https://doi.org/10.2991/978-94-6463-114-2_7

2 Experiment Procedures

The carbon content of the sample 1 and sample 2 are 0.23 (wt. pct), the carbon content of the sample 3 is 0.35 (wt. pct), the other main chemical composition of samples are Si, Mn, Al, Cr, B and Ti. The laboratory hot stamping simulation and the industry hot stamping use the same parameter, the austenitizing temperature is 930 °C and the holding time is 5 min. Sample 1 and sample 3 are heated in a furnace protected by nitrogen, but sample 2 is heated in a furnace without nitrogen protection. The hot stamping process of sample 1 and sample 3 is the same, but the difference is the carbon content.

The microstructure of the tested steel was observed by scanning electron microscopy (SEM, HITACHI S-3400N), the samples for SEM observations were etched with 4% nital. The ultimate cold bending test was conducted by the SANS CMT5305+, and the size of the sample is 60 × 60 mm, the surface of the sample was polished with 2000# sandpaper, and the surface of the sample is free of oxide skin, and the edge is smooth. Hardness testing was conducted using a FV-700 type digital Vickers hardness tester, with a load of 10 kg and 30 s dwell time.

3 Results and Discussions

Figure 1 shows the schematic illustration of the bending device according to the Verband der automobilindustrie standard VDA 238-100, and the experimental indenter with a radius of 0.4 mm, and the direction is parallel to the rolling direction.

Figure 2 presents the bending load-displacement curves of the tested steels, the ultimate cold bending angle of the sample 1, sample 2 and sample 3 are 66.1°, 77.4°, 40.8°, respectively.

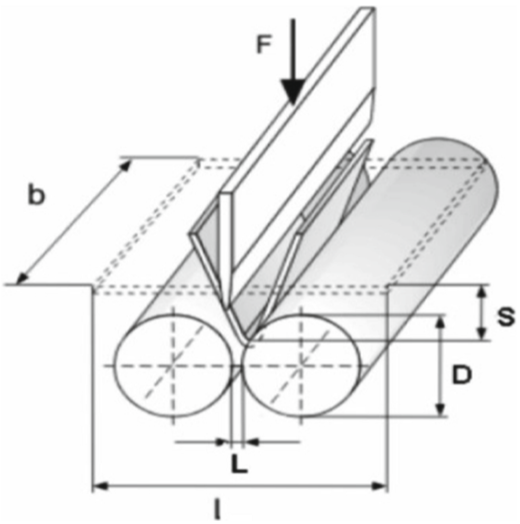

Fig. 1. Schematic illustration of the bending device according to the Verband der Automobilindustrie standard VDA 238–100.

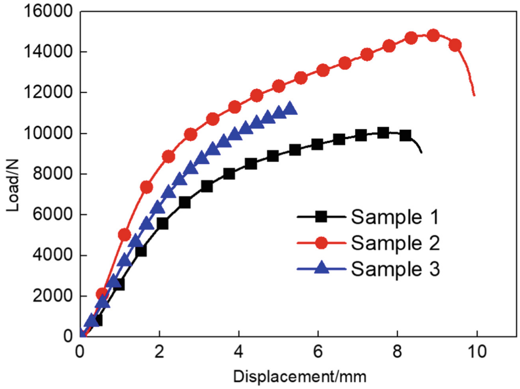

Fig. 2. The bending load-displacement curves of the tested steel.

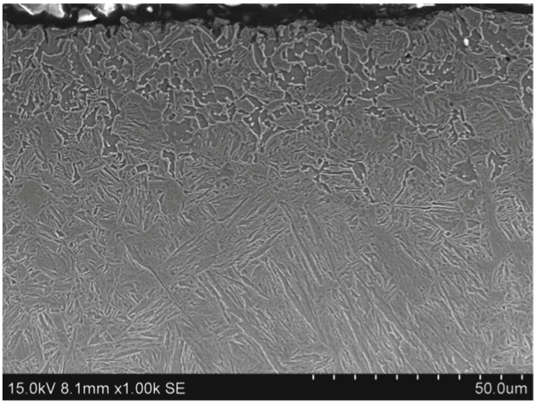

Fig. 3. SEM micrographs of the sample 1.

Figure 3 shows the SEM micrographs of the sample 1, there is decarburization at the edge of the sheet, which belongs to semi decarburization. The depth of the decarburization layer is about 20 µm. Figure 4 shows the SEM micrographs of the sample 2, the thickness of the full decarburization layer is 10 µm, and the thickness of the semi decarburization layer is 10 µm. Compared with the sample 1, the edge decarburization of the sample 2 is more serious.

From the comparison between sample 1 and sample 2, it can be found that the thickness of the decarburized layer is the key factor affecting the ultimate cold bending angle of the hot formed steels. In the microstructure of hot stamping steel, the existence of a certain decarburization layer is detrimental to ensuring strength and stiffness. Generally, complete decarburization layer is not allowed in industrial production, and the depth of decarburization layer should be less than 50 µm.

The hot stamping process of sample 1 and sample 3 is the same, but the difference is the carbon content. The carbon content of sample 1 is 0.23 (wt. pct), and the carbon content of sample 3 is 0.35 (wt. pct). From the comparison between sample 1 and sample

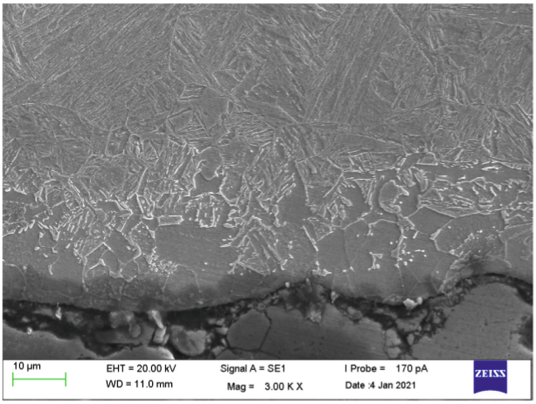

Fig. 4. SEM micrographs of the sample 2.

3, it can be found that carbon content is another key factor affecting the ultimate cold bending angle of hot stamping steel.

For the hot stamping steel, the microstructure after hot stamping is martensite, and martensite is the supersaturated solid solution of carbon, which has high hardness and strength. The higher the carbon content, the higher the hardness of martensite. For the steel with 0.23 (wt. pct) carbon content, the hardness after hot stamping is between 420–450 HV (HV10), while for steel with 0.35 (wt. pct) carbon content, the hardness after hot stamping is about 600 HV (HV10). For steel with 0.23 (wt. pct) carbon content, the ultimate tensile strength after hot stamping is about 1500 MPa, while for steel with 0.35 (wt. pct) carbon content, the ultimate tensile strength after hot stamping is about 2000 MPa. The ultimate cold bending angle of experimental steel decreases with the increase of hardness and ultimate tensile strength.

4 Conclusions

(1) The thickness of the decarburized layer is the key factor affecting the ultimate cold bending angle of the hot stamping steels.
(2) The carbon content is another key factor affecting the ultimate cold bending angle of hot stamping steels.
(3) The appearance of complete decarburization layer should be avoided in industrial production to ensure ultimate tensile strength and hardness.

Acknowledgements. This research was supported by the demonstration platform for production and application of agricultural machinery equipment and materials and the CITIC-CBMM Nb Steel Award Fund Program (No. 2021 FWNB30045).

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