Influence of Annealing Temperatures on Microstructure and Mechanical Properties of 22MnB5 Hot Stamping Steel

B. Yang, H. L. Liu(✉), T. Jing, and Y. Chen

R&D Institute of Benxi Steel Plates Co., Ltd., Benxi 117000, Liaoning, China
daliang_lhl@hotmail.com

Abstract. In this paper, the relationship between microstructure and mechanical properties of 22MnB5 hot stamping steel at different annealing temperatures was studied by optical microscope, scanning electron microscope and universal tensile test machine. The results showed that the tensile strength and yield strength decreased with the increasing of annealing temperature. When the pearlite was not spheroidized, the strength decline was due to the growth of grains caused by the diffusion of metal atoms during heating. When the pearlite was spheroidized, the solid solution atoms in the ferritic matrix of spheroidized pearlite were diffused and precipitated at grain boundaries. The solid solution atoms in the ferritic matrix were reduced and the effect of solid solution strengthening was reduced, which leads to the decreasing of the overall strength of the material.

Keywords: Annealing temperature · Microstructure · Mechanical property · 22MnB5

1 Introduction

Due to the increasing need for fuel efficiency, emissions reduction and safe design, high strength steels have become widespread in the automobile industry [1–3]. However, the using of high strength steels usually lead to unacceptably high stresses during forming and springback phenomena after forming. In recent decades, 22MnB5 hot stamping steel played a critical role in formability, crash intrusion resistance and weight reduction [4].

According to the requirements of thickness a surface quality, some hot stamping products can be produced by hydrogen annealing furnace. How to use different annealing temperature to change the grain size and microstructure of ferrite and pearlite, so as to change the mechanical properties of the material, so that it is suitable for different customer needs is worth studying topic [5–8].

This paper mainly studied the ferrite and pearlite under different annealing temperature change and different influence on mechanical properties, morphology research result explains the changes of the microstructure under different annealing temperature effect on the mechanical properties, has practical guiding significance to make annealing process, in order to reduce the intensity of the hot rolled steel plate after laid a solid foundation to meet the user's special demand [9, 10].

Y. Zhang and M. Ma (Eds.): ICHSU 2022, AHMST 2, pp. 42–47, 2023.
https://doi.org/10.2991/978-94-6463-114-2_6

Table 1. The chemical composition of 22MnB5 hot stamping steel.

C	Si	Mn	P	S	Als	Nb + Ti + V
≤0.35	≤0.50	1.00–2.00	≤0.030	≤0.005	≥0.01	Appropriate

2 Materials and Procedures

The test steel is 22MnB5 hot stamping steel plate produced by industry. Chemical composition of materials is shown in Table 1.

The hot rolled sample with thickness of 2.8 mm was cut into 4 metallographic samples of 30 * 30 mm and 6 tensile samples of 50 standard distance for annealing test. The annealing temperature was 610, 650 and 680 °C, respectively. The specific process was to heat the samples to 610, 650 and 680 °C with the furnace, hold for 6 h, and cool with the furnace. After annealing, the sample was cut along the cross section perpendicular to the rolling direction and corroded with 4% nitric acid alcohol. The microstructure was observed by optical microscope and SEM scanning electron microscope. Finally, the ZWICK universal drawing machine was used to study the changes of mechanical properties under different annealing temperatures and the effect of the changes of microstructure on the mechanical properties.

3 Results and Analysis

3.1 Microstructure

The hot rolled structure are ferrite and pearlite, with fine structure and uneven grain size, obviously banded, with a grain size of 4.88 um. After annealing at 610 °C, the microstructure is ferrite and pearlite. After heating, the ferrite grains grow up again with a grain size of 7.03 um. Compared with the hot rolled ferrite, the newly grown ferrite has even structure, and the pearlite is still lamellar. After annealing at 650 °C and 680 °C, the microstructure is ferrite and pearlite. After annealing, the pearlite is broken and spheroidized. The microstructure is fine and uniform without obvious banded structure, and the morphology is shown in Fig. 1.

During the annealing process at 650 °C and 680 °C, all the carbon solidly dissolved in austenite, relying on undissolved carbides, precipitated out in a non-spontaneous nucleation, completing the spheroidization process and forming spheroidized pearlite structures distributed on the ferrite matrix. In this process, some alloying elements (such as manganese) fail to completely dissolve and aggregate in the spheroidized pearlite, resulting in alloy enrichment. The specific morphology and enriched elements are shown in Fig. 2.

3.2 Mechanical Properties

The yield strength and tensile strength of the hot-rolled specimen are 820 MPa, 975 MPa and 16% respectively. The yield strength and tensile strength of the hot-rolled specimen decrease significantly after annealing. The specific mechanical properties are shown in Table 2, and the comparison of mechanical properties is shown in Fig. 3.

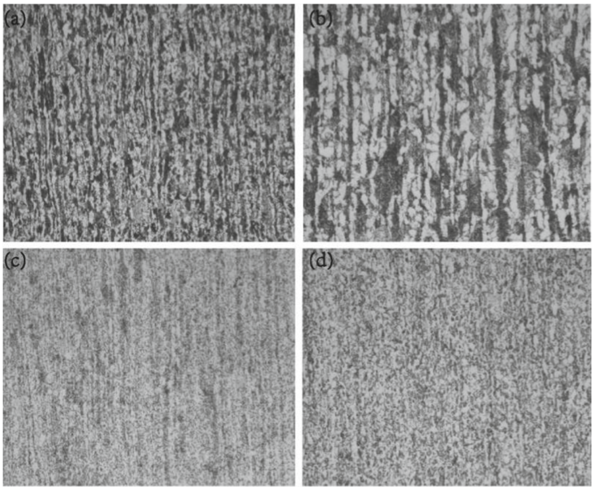

Fig. 1. The microstructure of different annealing temperature. (a) hot rolling; (b) annealing at 610 °C; (c) annealing at 610 °C; (d) annealing at 610 °C.

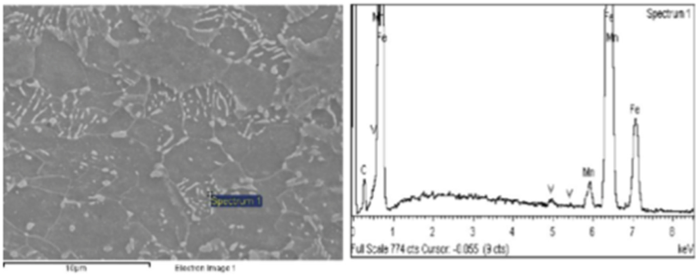

Fig. 2. SEM of alloy enrichment phenomenon of spheroidizing pearlitic.

Table 2. The specific mechanical properties of the specimens.

Sample	ReL/MPa	Rm/MPa	A50/%
RH	825	970	15.5
	815	980	16.0
610 °C	550	730	26.0
	570	740	22.0
650 °C	495	610	22.5
	485	610	24.5
680 °C	435	560	24.5
	435	570	23

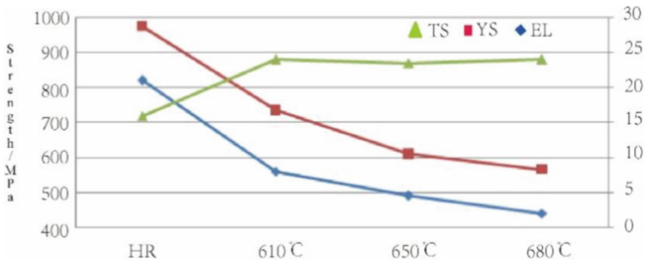

Fig. 3. The Comparison of mechanical properties between hot rolling and annealing.

4 Discussion

For hot rolling state and analyze the microstructure and properties of 610 °C annealing after, because water fast cooling after hot rolling, and ferrite grain is not fully grew up, therefore, ferrite grain size of hot rolled states small and uneven, and at the same time, pearlite piece of layered distributed at the grain boundary ferrite, to some extent, limits the ferrite grain growing up. With the increase of annealing temperature, pearlite spheroidization began. The so-called pearlite spheroidization refers to the process in which the cementite (carbide) in pearlite gradually transforms from lamellar structure to spherical structure and the subsequent spherical particles gather and grow up. Before the pearlite spheroidization, dislocation in encountered in the process of movement of lamellar carbide, due to the hard and brittle, is difficult to produce plastic deformation, the position of the dislocation in the layer of flake carbides plot plug, unless under the condition of large enough force, is it possible to overcome the resistance of dislocation and began to exercise, so think piece of pearlite lamellar structure has higher strength, After spheroidization, the strength will decrease greatly. With the increase of spheroidization, grain boundary carbides gather and fewer solid solution atoms are produced. The solid solution strengthening effect caused by solid solution atoms is weaker and weaker. As a result, the microhardness of ferrite decreases, and the overall strength of the material also decreases.

5 Conclusion

The microstructure of hot rolling and annealing is ferrite and pearlite. Compared with hot rolling at 610 °C, pearlite is still lamellar and the lamellar is thicker, and ferrite grains grow up again. The microstructure of pearlite after annealing at 650 °C and 680 °C is more uniform than that of hot rolling. It was found that the alloy elements (such as manganese) could not be completely dissolved in the spheroidized part of pearlite after annealing at 650 °C and 680 °C. It was found that when pearlite did not spheroidized, the main reason for the strength reduction was that the ferrite grain boundary overcame the restriction of pearlite and spontaneously diffused outwards, and the large grains ate the small grains and grew up again. At the same time, as a result of the pearlite spheroidization make ferrite matrix solution of atoms by dislocation, vacancy and grain boundary diffusion and near the grain boundary carbides formation, the accumulation of grain boundary carbides causes less solid solution atoms, solid solution strengthening effect is more and more weak, ferrtie microhardness therefore is reduced, the overall strength.

Acknowledgements. The work is supported by National Natural Science Foundation of China (No. U1908224), National Natural Science Foundation of China (No. U1708252), and Liao Ning Revitalization Talents Program (No. XLYC2007066). The Project was also sponsored by "Liaoning Bai Qian Wan Talents Program".

References

1. Z. X. Gui, Y. S. Zhang, H. Q. Li and M. T. Ma, Hot Stamping and Blank Designing for a Vehicle Bumper Using Ultra High Strength Steel (UHSS), *Advanced Materials Research* **2384**,690 (2013).
2. P. X. Liu, X. Y. Yu, K. Wang, B. Zhu, J. Li and Y. S. Zhang, A New Hot Stamping Process with Quenching and Partitioning Treatment, *Advanced Materials Research* **3857**, 1095 (2015).
3. S. Peng, J. Zhou, S. Qian, M. Zhang, J. Liu and Y. Meng, Study on new hot stamping tool with low cost and high cooling efficiency, *IOP Conference Series: Materials Science and Engineering* **1157** (2021).
4. C. P. Tong, Q. Rong, V. A. Yardley, X. T. Li, J. M. Luo, G. S. Zhu and Z. S. Shi, New Developments and Future Trends in Low-Temperature Hot Stamping Technologies: A Review, *Open Access Metallurgy Journal* **10** (2020).
5. L. Zhou, Y. W. Xu, X. P. Mao, G. W. Yang, S. Q. Bao, G. Zhao and X. D. Miao, Influence of Austenitizing Parameters on the Microstructures and Mechanical Properties of 22MnB5 Hot Stamping Steel Produced by TSCR Process, *Physics of Metals and Metallography* **121**, 1326 (2020).
6. A. Horn and M. Merklein, Functional optimization of hot-stamped components by local carburization, *International Journal of Lightweight Materials and Manufacture* **3**, 43 (2020).
7. C. C. Li and S. L. Xie. Microstructure and properties of hot stamping boron steel using heated dies under different holding time, *Vacuum* **170**, 108960 (2019).
8. V. Sarawagi, S. Narkhede, A. K. Singh and K. Narasimhan, Formability studies on 22MnB5 steel during hot stamping process conditions, *IOP Conference Series: Materials Science and Engineering* **418**, 012001 (2018).
9. S. Golling, D. Frómeta, D. Casellas and P. Jonsén, Influence of microstructure on the fracture toughness of hot stamped boron steel, *Materials Science & Engineering A* **743** (2018).
10. Z. M. Tang, Z. W. Gu, L. Jia, X. Li, L. J. Zhu, H. Xu and G. Yu, Research on Lightweight Design and Indirect Hot Stamping Process of the New Ultra-High Strength Steel Seat Bracket, *Metals* **9**, 833 (2019).