Nondestructive Testing of Medium Manganese Steel Based on Barkhausen

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Abstract. It is an effective means to make automotive structural parts of medium manganese steel, which is highly plastic, to achieve lightweight, but the martensite phase change occurs in the formation of manganese steel, which changes its mechanical properties and makes it difficult to evaluate the service performance of the parts. Therefore, the peak of Barkhausen noise (MBN) signal was studied, and the relationship curve based on MBN signal is obtained. According to the design stamping experiment of U-shaped parts of the same material, XRD and MBN test and verify the stamping steel properties respectively.

Keywords: Medium manganese steel · Barkhausen · XRD

1 Introduction

Advanced high-strength steel can realize the lightweight of vehicles from the perspective of material [1], reduce the consumption of fuel resources and exhaust emissions, which has become a research hotspot. In the current third generation of advanced high-strength steel, the application performance of medium manganese TRIP steel is the best [2, 3]. However, due to the existence of TRIP effect, the tissue structure of the processed medium manganese steel changes, which is not conducive to the evaluation of its service performance, and an effective detection method is urgently needed. Micromagnetic nondestructive testing technology directly detects the complex state and properties of ferromagnetic materials, which is suitable for medium manganese steel materials.

Medium manganese steel processing by stress produced strain, D. O'Sullivan [4]. After studying the ferrite stainless steel, the idea that the plastic deformation affects the dislocation density and causes the anticorrelation of the micromagnetic signal and the deformation size is proposed. The TRIP effect of medium manganese steel makes it produce a phase change at the same time of strain, and the corresponding strength of the micromagnetic signals of different microscopic tissues is obviously different [5]. Therefore, the phase transitions can also have an impact on the signal strength. The current research has deeply discussed the micromagnetic signal under deformation or phase transition alone, however, the micromagnetic signal of steel with both deformation and phase transition is relatively studied.

Y. Zhang and M. Ma (Eds.): ICHSU 2022, AHMST 2, pp. 408–413, 2023.
https://doi.org/10.2991/978-94-6463-114-2_54

This paper mainly studies the relationship between strain and micromagnetic signal in the process of strain and phase transition of medium manganese steel. The study aims to apply the actual measured tensile experiment results to the forming experiment of Chinese manganese steel, and finally obtain the nondestructive signal detection method that can be used in the practical engineering, and realize the application of tissue change detection, service performance evaluation, failure prediction and risk prevention of Chinese manganese steel.

2 The Manganese Steel Tensile Experiment

2.1 Materials

The preparation composition of this experiment has been determined as medium manganese steel sample and treated by annealing process. The steel is rolled independently by Northeastern University. The initial austenite content of Chinese manganese steel treated by this process is high, and more martensite is generated in the later period, which is conducive to the detection of micromagnetic signals. Table 1 shows the specific chemical composition and heat treatment process.

2.2 Design of the Tensile Experiments

For the tensile detection experiment of manganese steel in this study, Shimadzu AG-100kN electronic universal test machine was used with set tensile speed of 2 mm/min. The tensile sample of medium manganese steel as shown in Fig. 1 was taken for tensile experiment, and the micromagnetic signal probe was detected in real time. After each tensile process, it was measured three times in different measurement areas. During the stretching process, the detection probe measures the peak of the micromagnetic signal in the three positions online. The measured area of the probe and the tensile specimen and the field stretching drawing are shown in Fig. 2. After the tension ends, the stress and tension curve is generated with the help of the universal test machine. The correlation curve between the micromagnetic signal peak and the strain is obtained, and based on this correlation, the nondestructive detection of medium manganese steel can be achieved.

Table 1. Chemical composition and heat treatment process of manganese steel in the experiment.

Composition and process	C	Mn	Al	Si	Fe	The annealing process
Content (wt. %)	0.30	10.00	4.00	1.50	Bal.	800 °C for 1 h

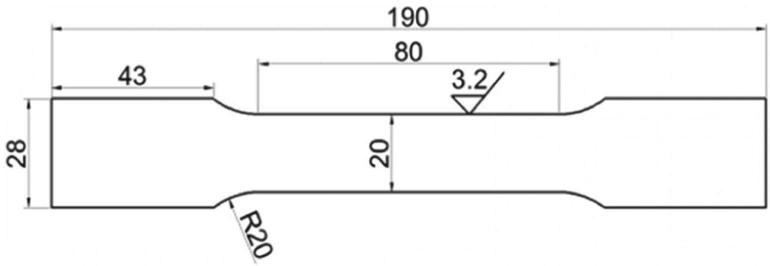

Fig. 1. Medium manganese steel test sample.

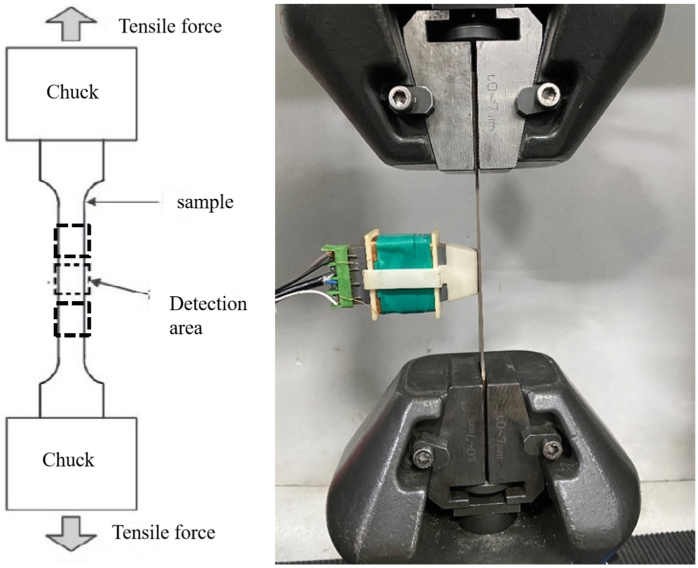

Fig. 2. Measurement area and site schematic diagram.

2.3 Experimental Results and Discussion

Figure 3 shows the peak of the micromagnetic signal under different strains, easily comparing the stress and strain curve in the same picture of the material. According to the preliminary observation, with the increase of strain, the peak of the micromagnetic signal increases in the whole, but in the early stage of plastic deformation, there are no small fluctuations, while in the elastic phase, there is a monotonous rise. In the whole process of elastic-plastic deformation, the corresponding relationship between the micromagnetic signal and the strain is more obvious, especially in the plastic deformation stage where the strain exceeds 8%, the two will rise monotonically in positive proportion.

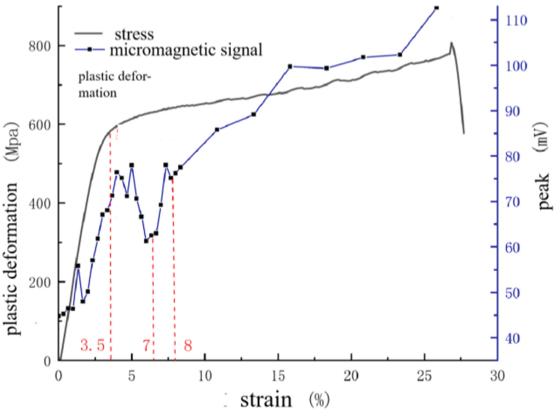

Fig. 3. Micromagnetic signal peak change curve with strain.

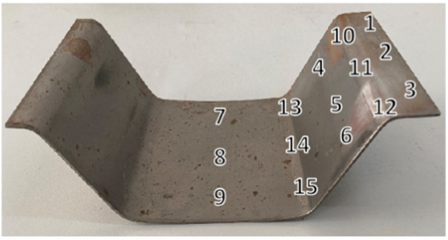

Fig. 4. U-shaped piece detection area.

3 U-Shaped Piece Forming Experiment of Medium Manganese Steel

3.1 Materials and Experimental Design

The medium manganese steel of the same material as the tensile test piece was selected, cut and made into U-shaped parts of 170 mm × 260 mm. Cut U-shaped parts directly using laboratory existing 2000 kN press. Mode speed is 50 mm/s, pressure is 1010 kN and pressure time is 5 s. The micromagnetic signal is detected on the flange, side, bottom side and two rounded surfaces of the formed U-shaped parts, and the detection value is compared with the peak curve of the stretching process to detect the strain degree (Fig. 4).

3.2 Results and Discussion

The regional micromagnetic signal peak value was detected on the stamped U-shaped parts. Figure 5 shows the results of the micromagnetic signal detection. Table 2 shows the micromagnetic signal measurements at different regional points. It can be seen that the signal peak of each part of the part is relatively close and distributed in different positions of the whole micromagnetic signal curve. The measurement value of the micromagnetic

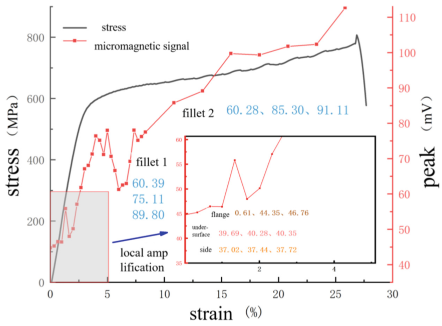

Fig. 5. The micromagnetic signal detection results in each region.

Table 2. Micromagnetic signal detection results in each area of Chinese manganese steel forming parts.

Measurement area	Micromagnetic signal detection result (mV)		
flange	Point 1 (40.61)	Point 2 (44.35)	Point 3 (46.76)
side	Point 4 (37.02)	Point 5 (37.44)	Point 6 (37.72)
underside	Point 7 (40.28)	Point 8 (40.35)	Point 9 (39.69)
Round Angle 1	Point 10 (89.80)	Point 11 (75.11)	Point 12 (60.39)
Round Angle 2	Point 13 (60.28)	Point 14 (85.30)	Point 15 (91.11)

signal at the bottom surface, the side surface and the flange is very low. Considering the error of the experimental instrument, the strain of the three parts is preliminarily determined to be 0, while the two different rounded angle areas should be distributed within the strain range of 5% to 10%.

4 Conclusion

The micromagnetic signal peak of medium manganese steel shows some correlation with the strain, and this relationship can be described by a relatively simple function expression. In this study, we detected the micromagnetic signal of the forming parts of medium manganese steel, and found that the peak value of each part of the part was distributed in different positions of the whole peak-strain curve. The measurement value of the micromagnetic signal at the bottom surface, the side surface and the flange is very low. Considering the error of the experimental instrument, the strain of the three parts is preliminarily determined to be 0, while the two different rounded angle areas should be distributed within the strain range of 5% to 10%.

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