Indication Analysis of Magnetic Particle Testing on PH13-8Mo Precipitation Hardening Stainless Steel

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Abstract. The abnormality indication which is detected using magnetic particle testing process of PH13-8Mo precipitation hardening stainless steel was analyzed, combine with the microstructure observation. The reason for the magnetic testing indication has been determined. Inhomogeneous microstructure is the main factor which causes the abnormal indication. The results provide an important basis for indication determinant in the magnetic particle testing process of martensitic precipitation hardening stainless steel.

1. Introduction
Martensitic precipitation hardening stainless steel has excellent properties, such as high strength, corrosion resistance, oxidation resistance and weldability, which has been widely used in important bearing components of aircrafts. Linear or hair lines magnetic marks often interfere the detection results of martensitic precipitation hardening stainless steel. The nature of the magnetic traces is difficult to determine which affects the results seriously [1-3].

In this paper, the magnetic particle detection test is carried out on the tower specimens and rod specimens of the PH13-8Mo martensitic precipitation hardening stainless steel raw material. Morphology of the interference magnetic traces are summarized. The reasons for its formation were determined by experimental comparison and microstructure analysis, which provided a basis for quality control in the production process of components.

2. Test materials and methods
PH13-8Mo martensitic precipitation hardening stainless steel has high strength, corrosion resistance, oxidation resistance and weldability, which is applicable to manufacture high-strength corrosion-resistant parts below 400°C, such as fasteners for airplanes and missiles, front and rear mounting edges of engine turbine casings, and valve parts. The resistance to atmospheric corrosion and acid corrosion is obviously better than that of martensitic stainless steel, which is comparable to some austenitic steels. It is not sensitive to hydrogen embrittlement, but under high-strength conditions, stress corrosion may occur. The surface of the sample has almost no traces of corrosion after being placed in artificial sea water and atmosphere for two years [4-6].

The magnetic powder inspection object is PH13-8Mo martensitic precipitation hardening stainless steel rods, with the diameter of φ20mm, and the heat treatment state is solid solution and aging. Perform purity inspection on the same batch of raw materials for the rods showing suspicious magnetic marks. The raw material supply state is solution heat treatment. The sampling method and
magnetic particle detection method are implemented in accordance with the AMS 2300 standard. The 1/2 diameter cylindrical sample of the raw material bar was intercepted, and the surface roughness was at least Ra 3.2. The sampling method is shown in Figure 1. Metallographic examination was carried out on the suspicious magnetic marks, and the microstructure morphology was analyzed.

3. Results and analysis

The PH13-8Mo steel rods with furnace number 018 was tested by magnetic particle, according to the standard HB/Z 72. When the current I=500A=25D, the magnetic traces are displayed as shown in Figure 2 (a). The linear magnetic marks in the straight axial direction show that the shape of the magnetic marks is similar to the metal streamline in the processing deformation direction, but it is clearer than the streamline, and some of the magnetic marks run through the end of the part. When reduce the current to I=250A=12.5D, the magnetic traces on the sample surface are displayed as shown in Figure 2 (b). At this time, the long and straight magnetic traces are not clear and belong to the normal fluorescent background. The residual magnetic method was further used to detect the magnetic powder of the sample. The test results are shown in Figure 2 (b), and the magnetic trace display is basically consistent with the magnetic powder display in Figure 2(b). The magnetic mark exclude the possibility of metallurgical defects such as grain. The microstructure of the test bar was analyzed. When the ferrite content was within the standard range, the magnetic mark caused by ferrite could be excluded. According to the morphology of the magnetic mark, it ran through the head and tail of the test bar, which was consistent with the rolling direction and characteristics. Therefore, it could be judged as the magnetic mark formed by the normal metal streamline.

According to the HB/Z 72 magnetic powder testing standard specification, the PH13-8Mo steel rod with 057 heats has been tested. When the current I = 500A = 25D, the magnetic mark is shown in Figure 3(a). It is found that the sheet magnetic mark is uniformly distributed on the surface of the specimen. When I = 250A = 12.5D, the magnetic marks on the sample surface are shown in Figure 3 (b). At this time, the sheet magnetic marks show a decrease in clarity. The residual magnetic method was further used to detect the magnetic powder of the sample. The test results are shown in Figure 3 (c), and the magnetic trace display is basically consistent with the magnetic powder display in Figure 3 (b). From the characteristics of magnetic marks, the magnetic marks at this time can exclude the possibility of metallurgical defects such as grain. Metallographic examination of raw material samples was carried out after sampling along the longitudinal direction. The metallographic structure is shown in Figure 4. Flake-like microstructure can be seen at low magnification, which is consistent with the characteristics of magnetic mark and the uniformity of microstructure is poor. Therefore, it can be determined that the magnetic mark is caused by the uneven microstructure.
The magnetic properties of raw materials were measured. The results are shown in Figure 5. It is found that the maximum relative permeability of raw materials is about 151, and the relative permeability is high, which is suitable for magnetic powder detection. The remanence is 0.6T, which is lower than 0.8T in the standard. However, it can be seen from the consistency of the two test results of reducing current and remanence method that the remanence of 0.6T also basically meets the requirements of magnetic trace verification.

4. Discussion

The results of magnetic particle detection and microstructure analysis of PH13-8Mo steel show that there is no linear defect such as hair crack, and no serious non-metallic inclusions in the material. It is concluded that the presence of magnetic powder has nothing to do with hair crack and non-metallic inclusions. Through the metallographic examination, it is further found that the long straight linear magnetic mark shows normal metal streamline magnetic mark, which can be verified by reducing the current or remanence method to distinguish from metallurgical defects. The sheet-like display is caused by the uneven microstructure, and the magnetic mark display is particularly obvious. The leakage magnetic field is large, and the reduced current and remanence methods are obviously displayed. Therefore, the sheet-like magnetic mark display seriously affects the evaluation and detection of magnetic mark display of other metallurgical defects. It is necessary to carry out relevant processing through the metallurgical sector to eliminate the interference of such abnormal magnetic marks.
5. Conclusions
(1) The metal streamline of PH13-8Mo precipitation hardening stainless steel rolling is the reason of long straight linear display in magnetic particle inspection process;
(2) The uneven microstructure of PH13-8Mo precipitation hardening stainless steel is the reason of flake display in the magnetic particle inspection process.

References
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