THE CHARACTERISTICS OF THE MAGNETIC MEMORY SIGNALS UNDER DIFFERENT STATES FOR Q235 DEFECT SAMPLES

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1. Background
Magneto-mechanical effect \[1\] refers to the phenomenon that the change of magnetization intensity was closely related to the change of mechanical stress or strain and other mechanical quantities. Magneto-mechanical effect has been attracting more and more attention because it is related to several technology problems \[2\] one of which is the magnetic memory testing technology. Magnetic memory testing was suitable for early damage detection in ferromagnetic material, in addition, it can help to find dangerous areas before the formation of macrocracks which cannot be realized by other NDT methods. It has great significance in preventing sudden failure.

The basic principle of metal magnetic memory testing can be stated as: under the earth magnetic field and the applied load, the magnetic domain structure of the ferromagnetic specimens has orientation and irreversible reorientation with the property of magnetostriction. Not only will this irreversible change of the magnetic state be retained when the load is eliminated, but also it is related to maximal work stress \[4-7\]. This magnetic state of the surface of ferromagnetic component records the state of micro-defect and stress concentration.

To make up the deficiency of this technology in quantitative research, comparison and analysis of the characteristics of the magnetic memory signals of Q235 in the three different test environments which are online-loading, online-unloading and offline-unloading were carried out. Different magnetic memory signals corresponding to different stress levels may be obtained.

2. Materials and experiment method
The material studied was Q235 carbon steel, which contains 0.12~0.20% carbon content. The yield limit of the material was 235Mpa and the strength limit was 370Mpa. All samples were in shape of plate with a defect with 3mm in width and 3mm in height as shown in Figure 1. The distance from the left end was 90mm, and it wasn’t at the medial position. Three samples were machined in order to avoid contingency. Demagnetizing process was done before the experiments. Experiments were done on Zwick II tensile testing machine. The loading speed was 2mm/min. Magnetic memory signals, \(Hp(y)\) value, were measured by the TSC-1M-4 tester of stress concentration.

Figure 1 Size of sample and measuring lines and points
Measurements of surface magnetic field were taken along the three lines L1, L2, L3 and eight points which are on the lines L1, L2 respectively. The measurements contained three different test environments which are online-loading, online-unloading and offline-unloading. For one sample, one cycle of the experiment contained five measurements. The first test was carried out before clamping fixture; the second one was performed after clamping fixture; the third one was performed on the testing machine when it has loaded to setting load; the fourth one was carried out after having unloaded to 0KN; the last one was performed when the sample was taken down from the tensile testing machine. The load was at interval of 2, 4, 6, 8, 11, 14, 17, 18, 19, 20, 21, 22 and 23KN, continuing loaded until fracture.

The samples should be kept vertical placement when tested.

3. Results

The test results of the three samples were similar, so taken the second sample as example. Sample yielded at load 19KN and necking at load 23KN. The sample was elongated 10mm. The width of the defect was elongated 3mm. The main results of different test environments as follows.

3.1. Magnetic field curves along line L1 with the change of load

![Figure 2](image)

(a) The change of the magnetic field under online-loading. (b) The change of the magnetic field under online-unloading (c) The change of the magnetic field under offline-unloading.

The curves under online-loading were performed on the testing machine as it has loaded to the setting load while the stress held constant. The curve of initial loading (until 2KN) and that of initial unloading were almost the same. As shown in Figure 2(a), they were marked by yellow. Small load didn’t arouse the change of magnetic memory signal. Magnetic memory signal curves were inclined to lines and they were stable when the load at the range of 2KN–19KN (yield load). As shown in Figure 2(a), they were marked by green. With further increase of the load 19KN (yield load), wave peak and wave valley were beginning to appear at the defect location. As shown in Figure 2(a), they were marked by blue.
The curves under online-unloading were performed when the machine was unloaded to 0KN. The sample was still clamping on the tensile testing machine. Before the load 13KN (about 0.7σ_s), the curves had little change, and the position of the defect couldn't be shown. As shown in Figure 2(b), they were marked by blue. When the load at the range of 13~19KN, wave peak and wave valley were beginning to appear at the defect location. As shown in Figure 2(b), they were marked by green. With the load further increasing, after the yield load 19KN, magnetic memory curves had a jump. The amplitude increased by 40A/m. Wave peak and wave valley still existed. As shown in Figure 2(b), they were marked by yellow.

The curves under offline-unloading were performed when the sample was taken from the testing machine. Tests were at the same position and the sample was kept vertically. The curve of initial loading and that of initial unloading were obviously different. As shown in Figure 2(c), they were marked by blue. But the position of the defect wasn't indicated. With the load increasing to 2KN, magnetic memory curves had a jump. The amplitude increased by 40A/m. As shown in Figure 2(c), they were marked by yellow. The signal became stable until great change happened on the verge of fracture.

3.2 Magnetic field curves along three lines at 23KN load

![Graphs](image)

Figure 3 The magnetic field value along three lines at 23KN load. (a) The change of the magnetic field under online-loading. (b) The change of the magnetic field under online-unloading (c) The change of the magnetic field under offline-unloading.

Magnetic memory signals along L1, L2 and L3 in the three different test environments at load 23KN were given in Figure 3. Conclusively, the magnetic field value along L1 was higher than the value of L2 and L3. The magnetic field value along L2 was higher than the value of L3. The curves were obviously in the three test environments. Firstly, the trends of curves were completely different. Secondly, the magnetic field curves along three lines under online-loading had obvious wave peak and wave valley. The magnetic field curves along three lines under online-unloading had wave peak and wave valley too. But the peak to peak value was 20A/m, lower than that of online-loading. The maximum value was 30A/m, higher than that of online-
loading. The magnetic field curves along three lines under offline-unloading didn’t have wave peak and wave valley. There were obvious jump at the defect location.

4. Conclusions

(1) Magnetic memory signal have different characteristics in the three different testing environments which are online-loading, online-unloading and offline-unloading. It is better to analysis the level of stress by the data of online-unloading because they can provide more information.

(2) The data of online-loading and that of online-unloading can present the yield and necking of the sample. Whether the material has been in yield can be judged by the appearance of wave peak and wave valley of the data of online-loading. The material has been in yield and necking can be judged by the appearance of wave peak and wave valley and sudden increase of the data of online-unloading.

(3) Information of stress distribution can be obtained by the surface magnetic field distribution. This is the foundation of quantitative evaluation. It is possible to evaluate the level of stress by the magnetic memory signals.

5. References


