Study on the characteristics of metal magnetic memory signal of X70 pipeline steel

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Abstract: In view of the zero crossing phenomenon of the normal component of the magnetic memory signal on the surface of the ferromagnetic component in the crack or stress concentration, many scholars have disputes about it. In this paper, through the simulation of the crack by wire cutting, the normal component of the magnetic leakage signal on the surface of the pipeline component is stretched on the tensile testing machine, and the normal component of the magnetic memory signal on the surface of the pipeline component is analyzed. It is found that the zero crossing phenomenon does exist in the normal component of the crack, but the zero crossing occurs with the pulling when the load increases to a certain extent, it will not drift after passing the zero point. The results show that the normal component cannot be used to judge the crack or stress concentration simply.

1. Introduction

Metal magnetic memory (MMM) detection method is a new NDT method proposed by Russian experts represented by Professor Dubov in 1997. As soon as this method is put forward, it gets the attention of the international community. Scholars at home and abroad begin to study the theory of MMM method and its application in the crack detection of components[1,2]. At present, in the research of MMM detection of component cracks, the main focus is on the MMM signal characteristics of component cracks. Professor Dubov, a Russian scholar, thinks that the normal component of magnetic memory leakage signal on the surface of ferromagnetic component has zero crossing point in judging the crack or stress concentration, but many scholars have doubts about it[3,4,5]. In order to solve this problem, the characteristics of metal magnetic memory signals of ferromagnetic components are studied.

2. Test scheme

2.1 Experimental object

In the test, X70 pipeline steel is taken as the test object, the length of pipe fittings is 200 mm, the inner diameter is 58 mm, and the outer diameter is 60 mm. The cracks with the depth of 0.5mm, 1mm and 1.5mm were processed by wire cutting at the distance of 30mm, 60mm, 90mm, 120mm and 150 mm from the end point to simulate the cracks. Connecting screws are machined at both ends of the pipe for fixing on the tensile testing machine as shown in Fig.1.

2.2 Experimental equipment
The static load tensile test was carried out on MTS810 hydraulic servo testing machine. Zsg-1036 type metal magnetic memory detector produced by Xi’an zhishenggao Electronic Instrument Co., Ltd. was used to measure the value $H_p(y)$ of magnetic leakage field on the surface of components.

2.3 Test Method

In order to study the MMM detection signal characteristics of specimens under different tensile forces, this paper has carried out four tests in the elastic deformation stage of stretching, each of which includes two parts, i.e. the test during loading and the test after unloading. The detection direction is shown by the arrow in Fig.1. When the specimen is loaded to a certain test force on the tensile testing machine, we keep the test force unchanged and carry out MMM test on the effective area of the specimen. All MMM tests start from the left end of the tensile specimen in Fig.1 and end at the right end. Detection conditions are showed in Tab.1.

| TABLE-1 Loading force of tensile sample during MMM test |
|---------------------------------------------------------|
| Tensile loading force (KN)                              |
| First time | Second time | Third time | Fourth time |
| Sample No.1 | 297     | 342      | 512   | 657   |
| Sample No.2 | 312     | 432      | 632   | 879   |
| Sample No.3 | 127     | 256      | 357   | 412   |

3. Analysis of test results

3.1 Characteristics of the magnetic memory signal at the crack

Taking sample No.1 as an example, under the tensile load, there is a large stress concentration at the prefabricated crack, and the normal component of magnetic memory leakage signal $H_p(y)$ has obvious zero crossing phenomenon, but with the increase of the tensile load, the zero crossing has obvious drift, as shown in Fig.2, 3, 4, 5.

After analysis, No. 2 and No. 3 samples also reach the same conclusion, which shows that with the change of tensile load, the normal component of magnetic memory magnetic leakage signal $H_p(y)$ shifts obviously.

3.2 Relationship between zero crossing position and tensile test force

In this paper, the relationship between zero crossing position and tensile test force in MMM test of tensile test is statistically analyzed. The statistic is the difference between zero crossing position and prefabricated crack position, which is defined as $\Delta Lx$. The same rule is obtained. Take the statistical results of the first crack at the left end of No. 1 test piece as an example, as shown in Fig.6. From Fig.6, it can be seen that at the lower stress level (the first loading stress), no zero crossing occurs. When the stress increases to a certain level, zero appears for $H_p$. As the stress continues to increase, there is a form of movement that tends to zero for $\Delta Lx$. When the stress exceeds a certain level, the stress continues to increase, and it will no longer change, but remain at zero.
4. Analysis and Discussion

From Fig. 2, 3, 4 and 5, it can be seen that when the load is increasing, the zero crossing position changes for $H_p(y)$, which is caused by the change of magnetic domain at the crack caused by the change of magnetic flux leakage signal when the load is increasing. In figure-5, the zero crossing position becomes dense, which is caused by the micro defects inside the component. When there is no load or small load, the internal micro defects have little impact on the magnetic flux leakage signal, while when the load increases, they affect the magnetic flux leakage signal on the component surface. Figure-6 of the statistical results more intuitively shows the zero drift phenomenon of the sample under different tensile loads. Under small load, the component does not have zero crossing, the load increases to a certain extent, and zero crossing occurs. At the same time, with the increase of load, zero crossing appears drift, and when the load increases to more than 600, zero crossing does not drift.

Further research shows that the $H_p$ zero point is the position where the stress changes most violently. These positions are often in the slip band and other positions where the micro structure and properties are not uniform. Due to the change of these specific positions under the action of stress, the phenomenon of zero shift is formed.

From the above analysis, it is easy to draw a conclusion that $H_p$ zero crossing is a kind of detection surface phenomenon. Because of its position drift, $H_p$ zero crossing is not the only reliable detection signal feature used to determine the crack position.

5. Conclusions

(1) Under the action of tensile load, the detection $H_p(y)$ signal of component surface appears zero crossing at the prefabricated crack, which indicates that there is a sharp change at the crack for $H_p(y)$.
(2) The $H_p(y)$ zero crossing position drifts with the change of tensile load, which shows that the zero crossing position is not a reliable detection signal feature to judge the crack position.

(3) When the tensile load increases to a certain extent, the $H_p(y)$ zero crossing position will not change.

(4) It is not simple to judge the crack or stress concentration by crossing the zero point of normal component, but also combined with other identification methods.

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