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Research on magnetic testing method of stress distribution①

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[Abstract] For implementing nondestructive evaluation of stress distribution inside ferromagnetic material, a magnetic testing method was developed which does not need artificial magnetizing field. This method was implemented by testing the normal component of the magnetic flux leakage above the object being tested with a constant lift-off from 1 to 10 mm. The distribution of the stress inside the specimen can be gotten from that of the normal component of the magnetic flux leakage. A stress concentration specimen, which is a 10 mm thickness mild steel plate with a welding seam on it, was tested using this method. The stress distribution of the magnetic testing was identical with that of small hole stress testing method. It indicates that the stress distribution of ferromagnetic material can be known by the magnetic testing method.

[Key words] magnetic testing; stress distribution; welding seam

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1 INTRODUCTION

Large stress in the component of structures will affect the mechanical properties[1], erosion-resistance, fatigue ability and dimension precision greatly. Researches on the distribution of residual stress in components, the value of stress and eliminating the damages induced by stress have become the focus.

Welding always brings concentration of stress into the zone of heat action[2]. Y-sloping-shape welding format is largely used in projects and this welding format produces stress in the jointed component inevitably because of restricted state by the welding seam.

The methods of residual stress measurement include destructive and nondestructive techniques[3]. Small hole drilling measurement, based on local residual stress releasing, is the most representative destructive method. The measurement is performed by releasing the residual stress of local part tested, then measuring the strains with extensometer and calculating the residual stress values according to the stress-strain relationship. The residual stress values tested by small hole method are more precise than other methods. But there are several shortcomings such as time-consuming, damaging the inspected component to a certain extent, difficult to carry out.

Non-destructive residual stress measuring methods include X-ray diffraction, BN, ultrasonic transmission, magnetic measurements, etc. X-ray diffraction stress testing is a relative mature method among all these nondestructive stress testing methods. But the depth of testing is no more than 30 μm restricts its largely use[4].

Magnetic residual stress measurement is a non-destructive method based on the change of magnetic properties in ferromagnetic materials under the action of stress. Firstly, the ferromagnetic material is excited by a strong magnetic field, and then residual stress will be measured according to the magnetostrictive effect or magnetic elastic effect[5~11]. This method has been reported as a simple and untouched measurement. But it has several drawbacks, such as heavy equipment, uneven magnetization and remanence. Most of all, it needs a strong magnetizing field in the testing.

A new stress testing method is given in this paper. This method can give the distribution of residual stress by testing that of the magnetic flux leakage above ferromagnetic material. It avoids the weakness of traditional magnetic stress testing by not adopting artificial magnetizing field.

The stress distribution of a specimen with a Y-sloping-shape welding seam is tested using this method. To validate the result, the same specimen is tested by small hole method. The stress distribution of the magnetic testing is identical with that of small hole stress testing method.

2 MAGNETIC STRESS TESTING METHOD

2.1 Specimen

The specimen tested was a No.20 steel plate, which has a Y-shape-sloping manual arc welding seam on it. To eliminate the shape influence of the fortified seam on the magnetic field, the higher part of the seam has planed until the seam has the same height with the motherboard. The thickness of the specimen was 10 mm. The mean width w of the seam was about 8 mm and the depth of it was about 7 mm.

2.2 Method

The specimen was placed horizontally in geomag-

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netic field and then the normal components of the magnetic flux leakage (MFL) were inspected with a constant lift-off h of 10 mm. The MFL signals were amplified and filtered, after that, A / D transform and sampling were performed. Finally, the digital MFL signals corresponding to those sampling points were transferred to PC for further processing by RS232. For geomagnetic field can be considered as a uniform field in the inspecting area, the MFL signals will reveal the residual stress in the specimen. Fig. 1 shows the testing method, the crossed points in the testing plane are MFL sampling positions.

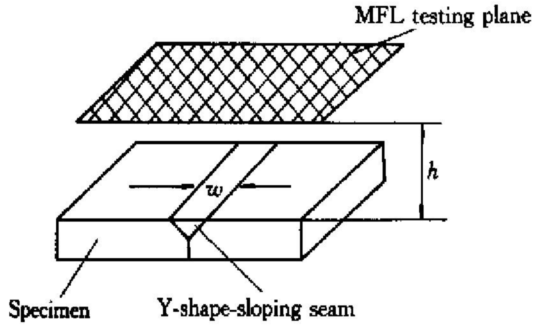

Fig. 1 Sketch map of MFL stress testing method

Fig. 2 shows a system which was developed for testing residual stress by MFL method. The magnetic probe in the system is a magnetic resistance device (MRD), the magnetic testing system module carries out the probe driving, amplifying and filtering of the MFL signals, A/D transforming and RS232 communicating functions. Those MFL signals over the specimen with 10 mm as lift-off were gotten by the scanning of a three-dimensional platform. The scanning platform was produced by aluminum alloy to avoid the influence on the distribution of spatial geomagnetic field. The welding seam of the specimen was placed horizontally along the direction of north-south on the platform.

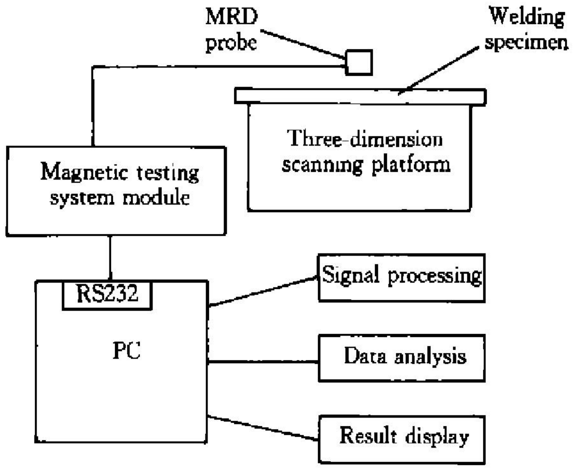

Fig. 2 Stress testing system by magnetic testing method

3 RESULT

The normal components of the magnetic field were inspected using above method. Fig. 3 shows the distribution of the MFL amplitudes. X coordinates show the positions away from the welding seam. Y coordinates show the positions along the welding seam direction. Vertical coordinates show the normal components of MFL amplitudes at different positions.

From Fig. 3, we can see that the amplitudes of MFL are not influenced by Y coordinates, they only varies according to X coordinates. To see the relationship between the normal components of MFL and X direction position more clearly, a curve intercepted from Fig. 3 is shown in Fig. 4. Its horizontal coordinates are the positions away from one side of the welding seam.

Small hole stress testing method was adopted to get the stress distribution near the welding seam. Fig. 5 gives the result. L is the distance from the

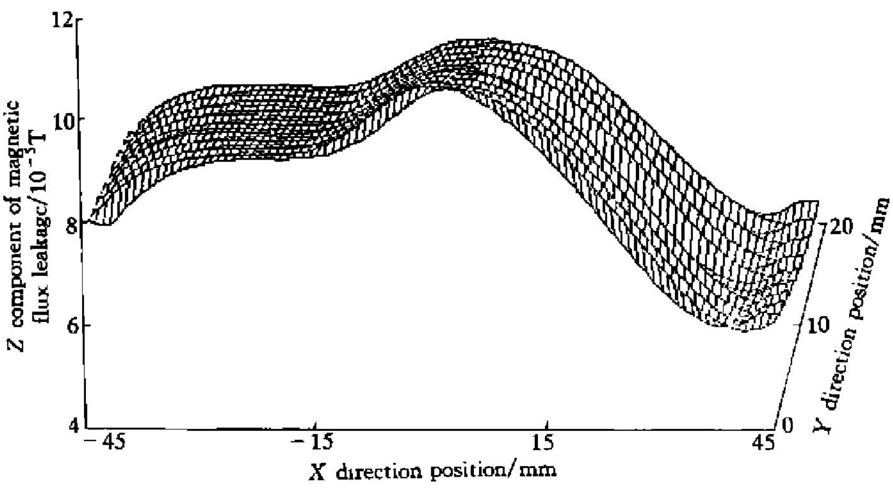

Fig. 3 Spatial distribution of normal components of MFL above 10 mm from specimen.

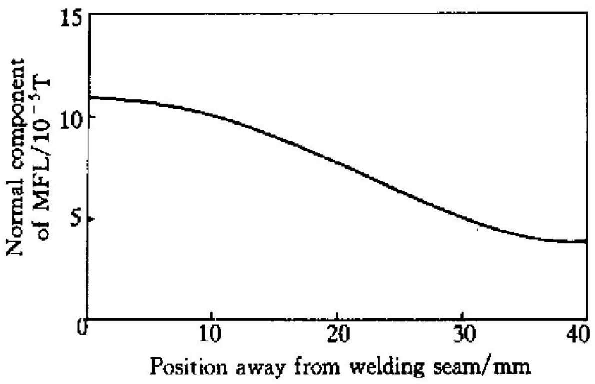

Fig. 4 One-dimensional distribution of normal components of MFL above 10 mm from specimen

stress testing position to the welding seam, σ_y represents the main stress parallel to the welding seam. Comparing Fig. 4 with Fig. 5, we can see that the normal components of MFL have accordant mutative trend to those of stress in the specimen. The tensile stress along the welding seam strengthens the normal components of MFL, and the compressive stress lessens them.

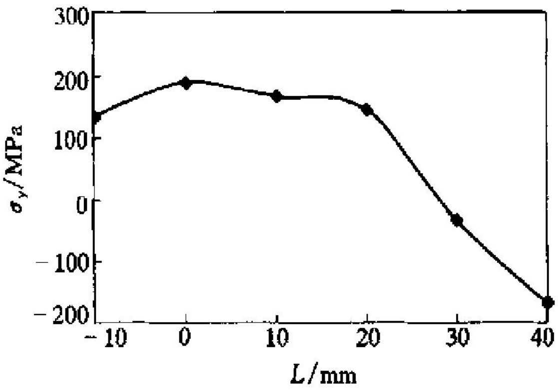

Fig. 5 Stress distribution from small hole drilling testing method

Fig. 6 gives the regularization curves of the magnetic signals and the stresses, in which N-MFL represents the regularization value of normal components of MFL, σ_{yR} represents the regularization value of main stress along the welding seam direction, and L shows the distance away from the welding seam. The two curves in Fig. 6 show very similar mutative trends and this is important for determining the stress distribution from MFL distribution.

4 ANALYSES

In multi-crystal ferromagnetic materials, if there is no magnetizing field and interior stresses, the probability of the directions of domains will be the same along all directions. So there is no magnetic flux leakage above the materials. The stresses in ferromagnetic materials will change the directions of domains and

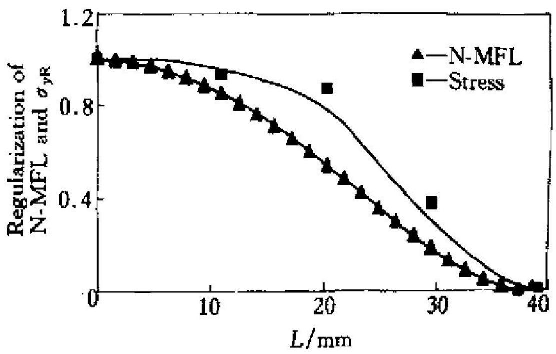

Fig. 6 Regularization of normal components of MFL and stresses vs distances away from welding seam

show as local magnetic characteristics anomaly, which will form magnetic flux leakage above the ferromagnetic materials. Tensile stress leads that the easy axes of domain trends to parallel to the stress and compressive stress results in the easy axes of domain perpendicular to the stress. In the experiment above, the tensile stress along the Y-axes direction conduces to the easy axes of domain parallel to it. The compressive stress along the Y-axes direction turns the easy axes of domain perpendicular to it. The magnitudes and directions of the stresses change according to stress concentration and lead to different magnetic flux leakage above the ferromagnetic materials. Thus, the accordant mutative trend of the normal components of MFL and Y-axes direction stress in the specimen can be explained successfully.

5 CONCLUSIONS

1) Residual stress in the Y-sloping-shape welding seam specimen affects the direction of domains in it and thus varies the normal components of magnetic field under the geomagnetic excitation. The distribution of stress can be gotten indirectly from that of normal components of MFL above tested ferromagnetic material.

2) The main meaning of this work is that it provides a simple and convenient nondestructive stress testing method. Using this method, the largest stress will be determined rapidly. The points, which have largest stresses, can be examined and determined the exact values by other methods. If the stress values of these points are less than the safe threshold, the whole tested object can be considered in a receivable stress condition.

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