VISUALIZATION OF HIDDEN CRACKS IN FERROMAGNETIC MATERIALS BY MAGNETOPTICAL METHOD

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A compact device has been developed that provides visualization of defects with a spatial resolution of 20 μm. The conducted studies have confirmed the effectiveness of the developed scheme for detecting cracks under the paint coating in steel structures, which opens up prospects for its use in industrial flaw detection.

Keywords: magneto-optical effect, hidden cracks, non-destructive testing of paint and varnish coatings

Introduction. The magneto-optical method of investigation, based on the Faraday effect, is one of the important methods of non-destructive testing of ferromagnetic materials. The Faraday effect consists in the rotation of the plane of polarization of light when it passes through a magneto-optical medium magnetized along the direction of propagation of the light beam. This phenomenon makes it possible to visualize the distribution of the magnetic field that arises around defects, such as cracks, pores or inclusions in structural materials.

Magneto-optical sensors [1], operating on this principle, are distinguished by high sensitivity to local changes in the magnetic flux and the ability to form contrast images of magnetic field leakage zones in real time. Unlike classical flaw detection methods, such as eddy current or ultrasonic testing, magneto-optical systems do not require contact with the object and are less sensitive to the geometric complexities of the surface, edges of the product, holes, etc. This makes them especially promising for the control of complex parts and thin-walled structures [2–3].

This work focuses on the creation of a compact magneto-optical device for detecting cracks in ferromagnetic samples and the study of its effectiveness. The use of the Faraday effect for optical imaging of the magnetic field distribution allows obtaining high-contrast images of defects and recovering information about their geometry, which is important for ensuring the reliability and durability of structures in industry.

Description of the installation. The developed magneto-optical device (Fig. 1.) for non-destructive visualization of cracks in ferromagnetic materials is implemented on the basis of an opto-electronic circuit that combines a light source, polarizing elements, a magneto-optical film, a registration system, and a magnetic system. LED radiation with collimating optics, located at an angle of 90° to the plane of the magneto-optical film, was used as a light source. To ensure normal incidence of light on the film, a beam splitter was used that deflects the beam in the desired direction. A polarizer is installed in front of the beam splitter to form linearly polarized light necessary for registering the Faraday effect. The magneto-optical film with a mirror layer applied to it performs the function of a working element that changes the plane of polarization of light proportional to the local magnetic field, and the mirror layer reflects the rays back to the system. The ferromagnetic control object is in close contact with the film surface, ensuring the transfer of the local magnetic field from defects. An external uniform magnetic field for magnetizing the sample and forming a magnetic field leakage in the crack zones is created by an electromagnet, the operation of which is regulated by a power supply and control unit.

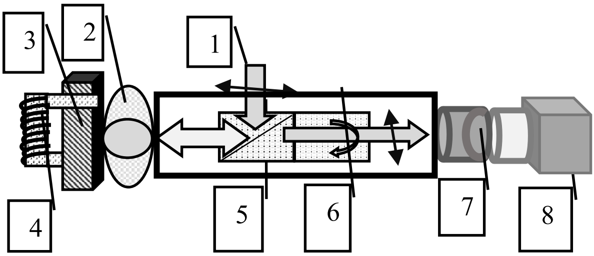

Fig. 1. Block diagram of a magneto-optical crack visualization device: 1 – light source; 2 – magneto-optical sensor; 3 – object of study; 4 – electromagnet; 5 – beam splitter; 6 – analyzer; 7 – lens; 8 – camera.

The light reflected from the magneto-optical sensor after passing through the beam splitter enters the analyzer, which extracts the changed polarization component due to the Faraday effect, and the digital camera receives the optical signal for further processing and visualization. The principle of operation of the device is that linearly polarized light, falling normally on the magneto-optical film, interacts with the magnetic field from defects in the sample, as a result of which the polarization plane changes. The reflected light, after passing through the analyzer, forms a contrast image of cracks, which is recorded by the camera.

Installation verification. Testing of the proposed installation was carried out on four specially prepared test samples of 38XS steel. In these samples, cracks of different sizes (see Table 1) were formed by cyclic loading, which reached the surface from one side and crossed the entire width of the samples. The overall dimensions of all samples were: thickness - 10 mm, width - 20 mm, length - approximately 50 mm.

In Fig. 2 shows magneto-optical images of cracks located under the paint layer. The images shown in Figure 2 were obtained after subtracting the reference image obtained in the absence of a magnetic field.

Table 1. Crack sizes in test specimens

Sample number	Width, mm	Depth, mm
1	0,052	3,75
2	0,046	2,32
3	0,031	2,36
4	0,066	0,25

To create a magnetic field in the research object, we used a ring bipolar electromagnet and a power supply unit developed by us with the ability to change the magnitude of the magnetic field by changing the current supplied to the winding. Changing the magnitude of the magnetic field makes it possible to search for defects of different sizes and types, which makes the proposed installation more versatile.

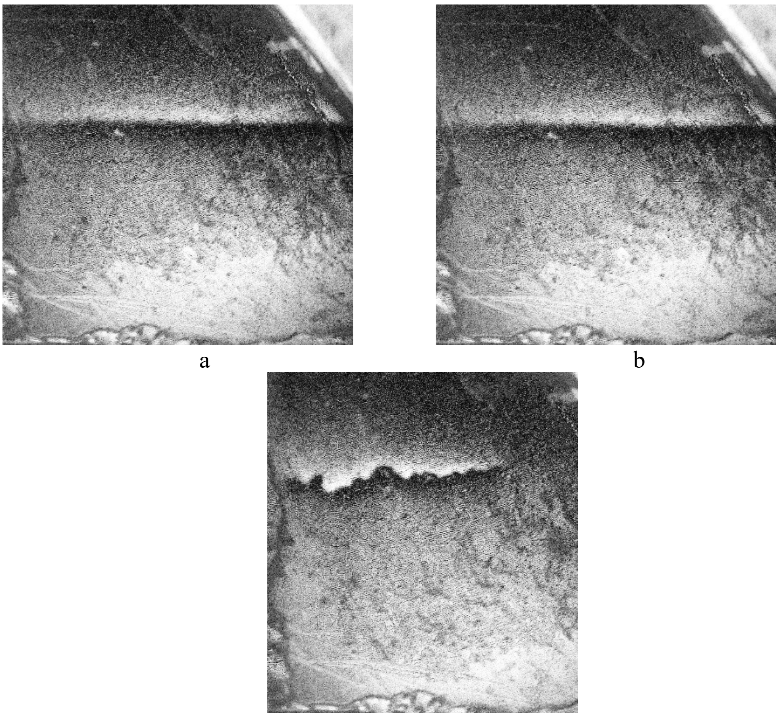

Fig. 2. Magneto-optical images of a crack: a – at a current of 0.9A; b – 3A; c – image of a crack in the end face of the sample.

Conclusions. The paper presents the development and experimental study of a magneto-optical device for non-destructive visualization of cracks in ferromagnetic materials based on the Faraday effect. The created installation allows you to effectively register magnetic field leaks in defect zones and form high-contrast images of surface and subsurface cracks in steel samples. Tests conducted on samples of 38XS steel with cracks of various sizes confirmed the operability of the system, its ability to localize defects and display their geometry. The results of the study indicate the prospects for using the developed device for non-destructive testing tasks in industry and in further research to improve magneto-optical visualization methods.

1. *Tehranchi M.M., Hamidi S.M., Eftekhari H., Karbaschi M., Ranjbaran M. The inspection of magnetic flux leakage from metal surface cracks by magneto-optical sensors // Sens. Actuators A: Phys. – 2011. – 172(2). – P. 365–368. https://doi.org/10.1016/j.sna.2011.09.010*
2. *Maksymenko O.P., Voronyak T.I., Stasyshyn I.V., Syvorotka I.I. Evaluation of the characteristics of ferrite garnet films for magneto-optical control of materials // Information Extraction and Processing. – 2024. – 52(128). – P.61–67. https://doi.org/10.15407/vidbir2024.52.061*
3. *Stasyshyn I., Suriadova O. Application of the magneto-optical effect in non-destructive testing // Materials Science and Surface Engineering: MSSE2023 Proceedings. – 2023. – P.235–238. https://doi.org/10.15407/msse2023.235*