New Methodology of Testing the Stress Dependence of Magnetic Hysteresis loop of the L17HMF Heat Resistant Steel Casting

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Abstract:
This paper presents the results of investigation on the tensile stresses dependence of magnetic characteristics of the L17HMF steel casting. To ensure uniform stress distribution in the sample for this investigation and the closed magnetic circuit, the frame-shaped samples were used. This is very important because it provides results independent of the shape and dimensions of the sample. On the columns of the sample both sensing and magnetizing windings were made. It is highly recommended to wound magnetizing and sensing windings on both columns. Due to the specialized force reversing system, compressive force generates the uniform tensile stresses in the sample. Magnetic characteristics are measured under these stresses by digitally controlled hysteresis graph. On the base of results of measurements the magnetoelastic characteristics of L17HMF steel casting were determined. Determined this characteristic is necessary to developed nondestructive testing method for monitoring of industrial and energetic constructions with elements made by L17HMF steel casting.

Keywords*: nondestructive testing, magnetoelasticity*

1. Introduction

Steel casting L17HMF is commonly used as a material for construction of elements of energetic infrastructure [1]. Due to the fact that components work at increased, state of material of these construction have to be intensively monitored.

There are different available methods of non-destructive testing. Among them, magnetic properties oriented methods have distinct advantages [2, 3]. First of all, NDT may be realized during the operation of equipment and infrastructure, which reduces maintenance costs. Moreover, magnetic tests based on magnetoelastic characteristics of the material are contactless, which greatly simplifies the process of surface preparation of the element tested [4, 5]. Additionally, magnetic field generation, in the range of energy and frequency used for NDT, doesn't create health risks for human operator, which is significant advantage in comparison with the use of X-ray and gamma radiation.

Nonetheless, magnetoelastic characteristics oriented methods of non-destructive testing are not widely used in industry applications. The main difficulty to overcome in such an industrial application is the lack of knowledge about magnetoelastic characteristics [6] of specific types of steels used in energetic industry. One example, commonly used in industry, would be the L17HMF steel casting. This lack of knowledge is directly connected with the lack of simple, unified methodology of the magnetoelastic characteristics of industrial types of steel testing.

This paper focuses on filling both of these gaps. It presents industrial-grade application oriented methodology of magnetoelastic testing of frame-shaped samples made of different kinds of steels. Moreover, results of magnetoelastic investigation of L17HMF steel casting are also presented, together with guidelines for stress assessment.

2. Method of Investigation

For the magnetoelastic tests of different kinds of steels, unified frame-shaped sample was designed. The sample is presented in the Figure 1. On the side columns of the sample both sensing and magnetizing windings were made. It is highly recommended to wound magnetizing and sensing windings on both columns. Moreover, sensing winding was located under the magnetizing winding, to reduce demagnetization effects. In the presented research, sample was wound by 500 turns of magnetizing winding (250 turns on each column), and 200 turns of sensing winding (100 turns on each column of the frame-shaped sample). Calculation of effective magnetic path length as well as effective magnetic cross-section of the frame-shaped sample was done in accordance to "Calculation of the effective parameters of magnetic piece parts" [7].

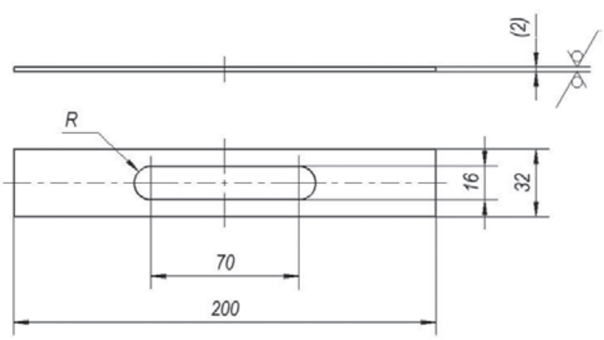


Fig. 1. Frame-shaped sample for the magnetoelastic tests

The hysteresis loops measurements are done on a test stand. The test stand composed of hysteresisgraph and personal computer. Hysteresisgraph HB-PL30 is composed of: voltage current converter and fluxmeter. The software generates magnetizing

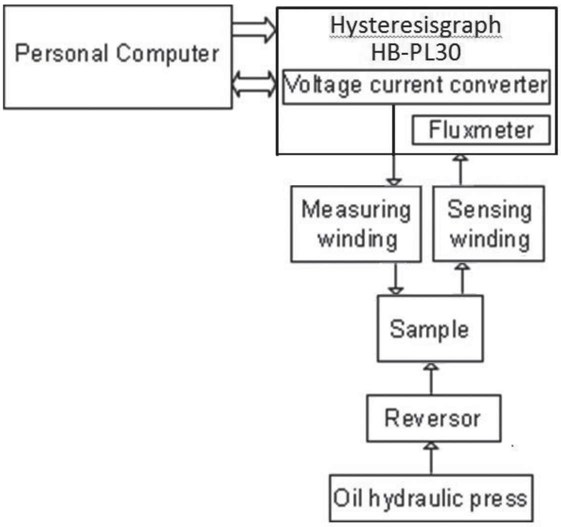


Fig. 2. Schematic block diagram of computer controlled hysteresis graph system for magnetic and magnetoelastic testing

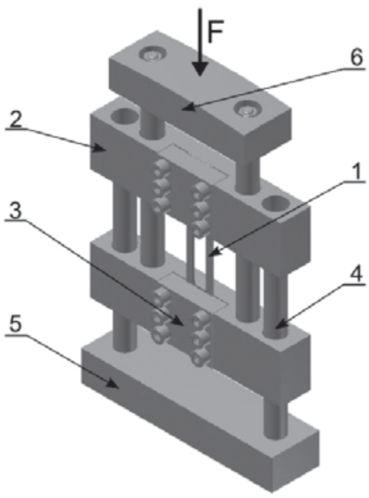


Fig. 3. Mechanical setup for testing the magnetic and magnetoelastic properties of frame-shaped samples: F – compressive force, 1 – tested frame-shaped sample, 2 – moving bar, 3 – sample holder, 4 – cylindrical columns, 5 – base of the device, 6 – upper bar

voltage signals, and next given them to the voltage current converter. The current flows through the magnetizing winding. Sensing winding is connected to the fluxmeter. The voltage induced in the sensing winding is measured and converted on the flux density value. The principles of applying tensile stresses with the use of oil hydraulic press were described previously [6]. In order to investigate the basic magnetic properties of the given construction steel, three conditions have to be fulfilled. The first condition is the obtaining of the closed magnetic circuit in the sample is necessary. Then the influence of the demagnetizing field on the measurements is greatly reduced, and the influence of the sample shape is nearly eliminated. The second condition is uniform stress distribution along the whole magnetic circuit in the investigated sample. Acquiring this condition allows for elimination of the stress influences reducing, which may happen when there are positive stresses in one part of the sample, and negative in another. The third, equally important condition is making the distribution of the effective stresses parallel or perpendicular to the magnetic patch direction in the sample.

Figure 3 presents the general view of mechanical setup for the magnetic and magnetoelastic properties of frame-shaped samples testing. With the use of this system, the compressive force F can be converted to uniform tensile stresses in the columns of tested frame-shaped sample. It should be indicated, that precisely controlled compressive force F can be easily generated by e.g. oil press.

3. Results

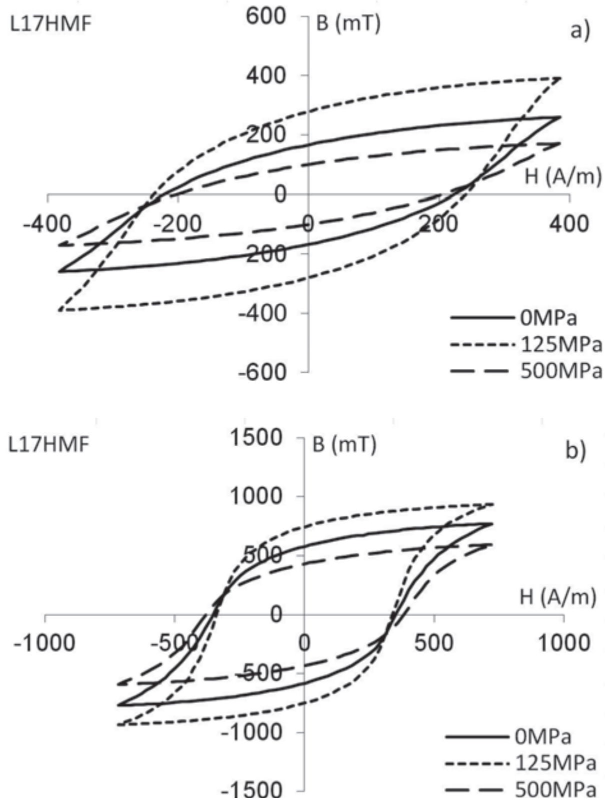
Figure 4 presents the experimental results of measurements of stress dependence of magnetic characteristics of frame-shaped samples made of L17HMF steel casting. Stress dependence of the shape of magnetic hysteresis B(H) loops may be observed for different values of amplitude of the magnetizing field H_m. There are distinct changes of the basic magnetic parameters: flux density, amplitude permeability. From the point of view of industrial utilization, changes of flux density and amplitude permeability are the most interesting.

Figure 5 presents the magnetoelastic $B(\sigma)_{Hm}$ characteristics, while the figure 6 presents the stress σ dependence of amplitude permeability μ_a. Under the tensile stresses value of the flux density B in the sample first increase, and then, after reaching the Villari point [8], it starts to decrease. It should be noted, that this decrease starts to be the most significant for stresses σ of about 150 MPa, which are connected with the change from elastic to plastic deformation of sample made of L17HMF steel casting. Moreover, these changes are relatively higher for the lower values of amplitude of H_m magnetizing field. This occurs due to the fact, that for lower values of magnetizing field H_m, participation of magnetoelastic energy in the total free energy is significantly higher.

Similar phenomena may be observed on stress σ dependences of amplitude permeability presented in Figure 6. After reaching stresses σ connected with plastic deformation, value of amplitude permeability μ_a starts to change rapidly. This effect is connected with the hardening of the L17HMF steel casting under plastic deformation.

4. Conclusions

The presented method of magnetoelastic testing of frame-shaped samples made of constructional steels opens the new possibility of filling the gap connected with the lack of information about these characteristics. With the use of this method, the database covering wide variety of steels may be developed, creating the industry-compatible possibility of nondestructive tests of constructional elements.



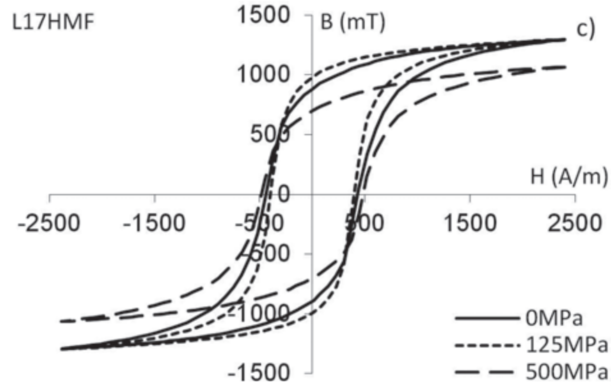


Fig. 4. The tensile stresses dependence of magnetic B(H) characteristics of frame-shaped samples made of L17HMF steel casting, for the three amplitudes H_m of magnetizing field: H_m=384 A/m, b) H_m=720 A/m, c) H_m=2400 A/m

The presented results indicate that magnetoelastic characteristics of L17HMF steel casting won't enable small values of tensile stresses σ assessment. However, for larger values of tensile stresses, which are in the range near the change from elastic to plastic deformation, both flux density B and amplitude permeability μ_a start to change rapidly, giving clear and reliable signal, which is important from the point of view of non-destructive testing. On this basis, the most dangerous stress occurrence can be detected. For this reason, presented experimental results confirm feasibility of use of magnetoelastic effect in non-destructive testing of construction elements made of L17HMF steel casting.

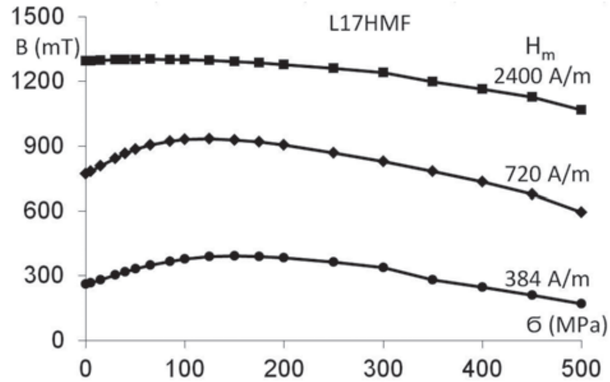


Fig. 5. The tensile stresses σ dependences of flux density B in L17HMF steel casting, for three value of amplitude of magnetizing field H_m

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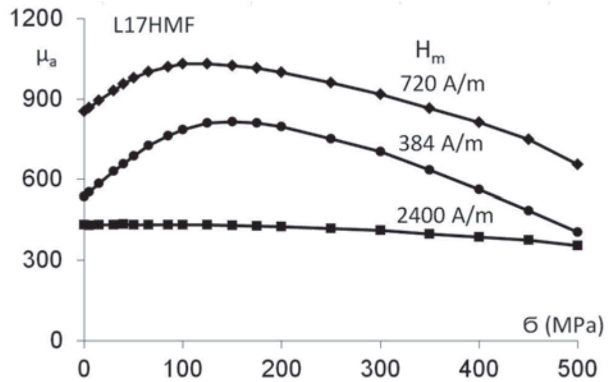

Fig. 6. The tensile stresses σ dependences of amplitude permeability μ_a in L17HMF steel casting, for three value of amplitude of magnetizing field H_m

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