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Methods of Demagnetization of Products and Devices of Railway Automation and Telemechanics

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ABSTRACT: The purpose of this work is to develop methods and devices degaussing rail lashes. Magnetization in railway transport plays an important role for the safety of train traffic. Therefore, it is necessary to develop methods and devices for the demagnetization of products in railway automation and remote control, which is an urgent task. The residual magnetization leads to swelling of the welded joints of the rails, which leads to the formation of cracks, which can lead to train accidents during their movement. During the operation of the railways, magnetization also occurs due to the rotation of the wheel sets and the actions of the reverse shunt current during braking.

KEYWORDS: ferromagnet, magnetization, degaussing, electromagnet, induction, rail, tension.

I. INTRODUCTION

During the construction and operation of rails, as well as during their manufacture at smelters, where induction furnaces are used, as well as during their transportation, they are magnetized, that is, they acquire residual magnetization [1]. Magnetization persists for a long time.

The residual magnetization leads to swelling of the welded joints of the rails, which leads to the formation of cracks, which can lead to train accidents during their movement. During the operation of the railways, magnetization also occurs due to the rotation of the wheel sets and the actions of the reverse shunt current during braking [2].

The magnetized parts and devices of ferromagnetic materials need to be demagnetized to eliminate the influence of residual magnetic fields [3]. These devices and products are considered to be demagnetized if the magnetization vectors of the spontaneous magnetization regions are randomly arranged and the average magnetization (induction) in any section of the product is zero or less than the value specified by technical conditions or regulatory documents [4].

II. METHODS AND RESULTS

According to the methods, demagnetizing devices can be divided into three types: mechanical, temperature, electromagnetic (Fig. 1.).

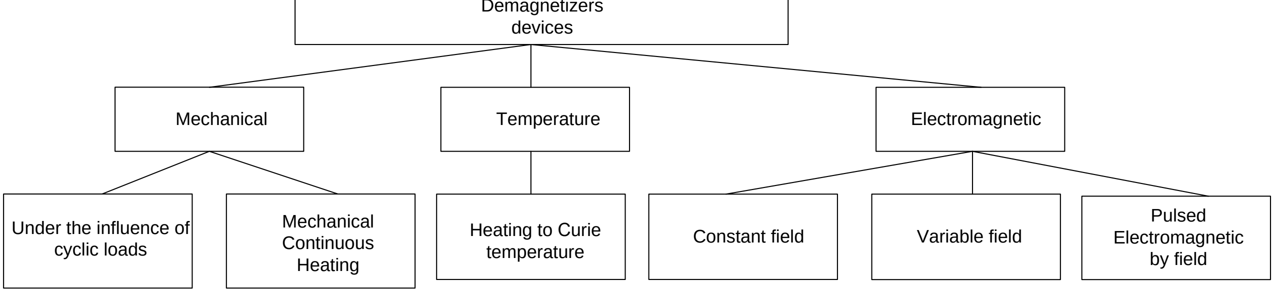

Fig.1. Classification of degaussing devices according to the methods

The mechanical method consists in demagnetization of a material under the action of cyclic or continuous mechanical loads. This method is not suitable for degaussing rail lashes and automation devices, for technical reasons [5].

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The temperature method consists in heating products or devices up to the Curie temperature (for steel 768^{0}C rails) [6]. At this temperature, the ferromagnetic materials disrupt the uniform direction of orientation of the domains. This method of demagnetization is also unacceptable, since mechanical properties, such as strength, rigidity and others, are lost [7].

The most common methods of demagnetization is the demagnetization of products and devices in an alternating magnetic field, decreasing in amplitude [8]. The product undergoes cyclical magnetization reversal by an alternating field, the strength of which, in amplitude with each half-period, decreases to zero (Fig.2), that is, $H_{m0} > H_{m1} > H_{m2} > H_{m3} > H_{m4} \ldots > 0$.

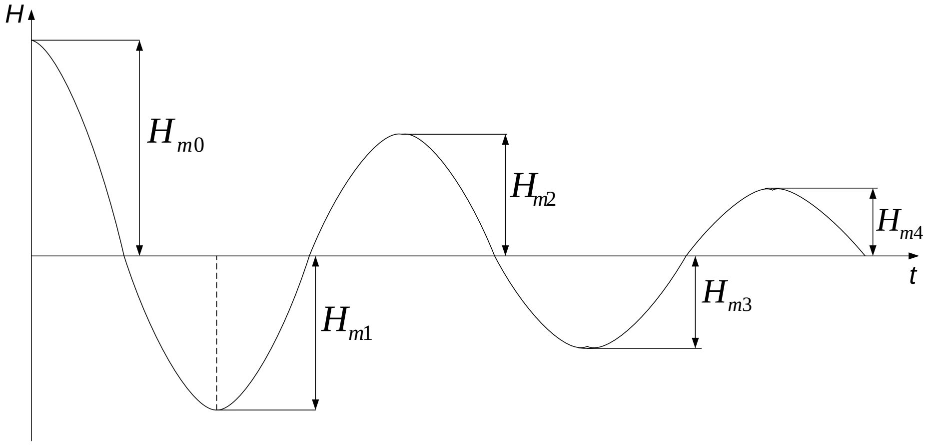

Fig.2. The change in magnetic field strength over time

For the point in time at which the induction reaches zero, the residual induction will also be close to zero (Fig.3).

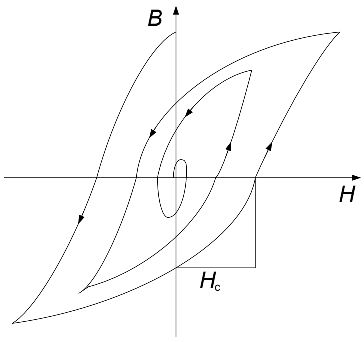

Fig. 3. Illustration of the essence of the demagnetization of private hysteresis loops

Let us find out the causes of magnetization of materials and products from ferromagnetic material. Any substance introduced into a magnetic field is magnetized. Inside the molecular currents, under the action of an external field, their magnetic fields are oriented in a certain way, and when they combine with an external field, it changes it, that is, it magnetizes. The intrinsic macroscopic magnetic field of a substance can be characterized by the vector $\bar{J}$, which is called the magnetization vector.

The relationship between the three magnetic field vectors by induction $\bar{B}$, strength $\bar{H}$, and magnetization $\bar{J}$is written as:

$$\bar{B} = \mu_0 \bar{J} + \mu_0 \mu \bar{H} = \mu_0 (1 + K_M) \bar{H} = \mu_0 \mu \bar{H} = \mu_a \bar{H}, \quad (1)$$

where $\mu = 1 + K_M$, is the magnetic permeability; K_M is magnetic susceptibility.

The magnetization will determine how much magnetic induction in a given medium $\bar{B} = \mu_a \bar{H}$ differs from magnetic induction in a vacuum $\overline{B_0} = \mu_0 \bar{H}$ at the same magnetic field strength. All substances have magnetic

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properties. The magnetic permeability for the material of rail lashes is $\mu \approx 10^2 \div 10^4$. It is variable and depends on H, that is, $\mu = f(H)$.. Thus, by changing the current in rail lashes, which is inextricably linked with induction according to the law of Bio-Savart-Laplace:

$$H = \oint_L \frac{I[dl\,1_R]}{4\pi R^2} \quad (2)$$

The change in the magnetic induction in the rail material, even at the same current value, is explained by the fact that the magnetic field is excited not only by the current passing through the conductor, but also inside the molecular currents of the substance surrounding the conductor. Therefore, the material of the rails can be magnetized and a change in the magnetic field of the Earth. Thus, demagnetizing the material of the rails is possible by acting on an alternating field with a decrease in amplitude. In this case, there are two procedures for the execution of this method of demagnetization.

The first way is to reduce the magnitude of the demagnetizing field or remove the solenoid from the rail scourge. The second is to reduce the current in the coil of the solenoid.

To automatically reduce the current, turn on the solenoid and gradually within 5 seconds remove it to a distance of 0.5meters, after which the solenoid is turned off. According to Figure 3, the residual induction decreases, that is, demagnetization occurs through partial cycles of hysteresis loops. The number of periods is usually not less than 40 ÷ 50, the decrease of the amplitude occurs smoothly. With this method of demagnetization, there remains a residual induction in rail lashes. Usually, they are demagnetized to a level at which the normal operation of railway automation systems is not disturbed.

For railway rolling stock, limits have been established for residual magnetizing fields of no more than H=500A/m, which corresponds to induction B=0.06T. The most common method is the demagnetization of rail lashes and devices by an alternating magnetic field. Consider the propagation of an alternating electromagnetic field in a massive ferromagnet, which is a rail whip. The electromagnetic wave, perpendicular to the rail surface, varies according to the law:

$$\dot{H} = H_0 e^{-kz} \cdot e^{-jkz}, \quad (3)$$

where H_0- is the demagnetizing field strength on the rail surface at z = 0; z-current field propagation coordinate; -attenuation coefficient and phase coefficient, equal to each other, are determined by the expression:

$$k = \sqrt{\frac{\omega \mu_0 \mu \gamma}{2}}, \quad (4)$$

where is the frequency of the demagnetizing field; μ-relative magnetic permeability; γ-specific conductivity of the rail material.

From the formula (3) it is seen that the amplitude of the magnetic field strength decreases according to the exponential law. The depth of penetration of an electromagnetic wave into the thickness of a rail scourge is equal to:

$$\Delta = \frac{1}{K} = \sqrt{\frac{2}{\omega \mu_0 \mu \gamma}}. \quad (5)$$

Wavelength:

$$\lambda = \frac{2\pi}{k} = 2\pi\Delta. \quad (6)$$

The initial phase of electromagnetic oscillations varies in proportion to the depth of their propagation. Moreover, measures of penetration of electromagnetic waves into the depth of the rail electromagnetic oscillations are late in phase compared to the surface by the value of $t - \frac{\Delta}{\vartheta}$, where the wave propagation velocity is:

$$\vartheta = \frac{1}{\sqrt{\varepsilon \varepsilon_0 \mu_0 \mu}}. \quad (7)$$

The depth of penetration of an alternating demagnetizing field into a rail whip is determined only by the frequency of this field. A graph of the depth of penetration of an electromagnetic wave into the cavity of a rail as a function of frequency is shown in Figure 4.

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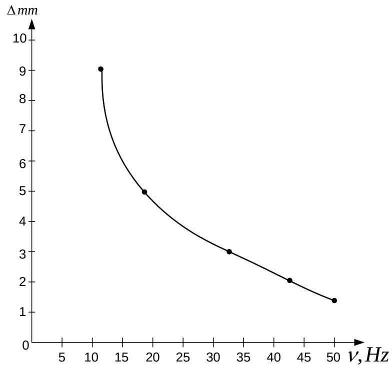

Fig.4. The dependence of the depth of penetration of electromagnetic wave into the cavity of the rail scourge

The ferromagnetic material of a rail scourge has a magnetic permeability $\mu = 10^3$ and conductivity $\gamma = 10^7 \frac{См}{м}$. As can be seen from the graph, the lower the frequency of electromagnetic waves, the greater the penetrating power of them. So for a frequency of 12 Hz, the electromagnetic wave penetrates deep into the rail of the rail to a depth of 9 mm.

The propagation energy of an electromagnetic wave is characterized by a Poiting vector, the average value of which is determined by:

$$\Pi_{cp} = \frac{H_0^2 \cdot \sqrt{2}}{4} \sqrt{\frac{\omega\mu}{\gamma}} e^{-2z\sqrt{\frac{\omega\mu\gamma}{2}}}. \quad (8)$$

III. CONCLUSION

From the formula (8) it is seen that the distance from the surface of the rail lash, equal to the wavelength λ deep into the rail lash penetrates only 0.2% of the energy absorbed by the material of the rail lash.

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