EFFECT OF LASER TREATMENT STRESS ON THE MAGNETIC PROPERTIES OF GRAIN–ORIENTED ELECTRICAL STEEL

Dragoshanskii Yu.N., Karenina L.S., Pudov V.I.

Institute of Metal Physics, Ural Division, RAS, Ekaterinburg, Russia.
Drago@imp.uran.ru

Introduction

In modern grain-oriented electrical steels with optimal or perfect (110)[001] crystallographic texture is coarse crystals dimensions and the domains magnetization vector oriented so that it induces no magnetic fields over the ribbon surface. This causes the growth of 180 ° strip magnetic domain dimensions, velocity their of boundary and eddy current losses [1, 2]. The reducing of magnetic losses can be achieve by applied of cover stress [3, 4] and local laser treatment. Local laser treatment of surface of the steel related to the formation of transversely oriented magnetostructural barriers in the form of narrow zones differing in structure from the main material [5, 6]. Applied to the steel ribbons of local laser treatment to lead to lower (in 2 – 3 time) domain width (Fig. 1) and magnetic losses by means reducing of their eddy current component [7]. Simultaneously with decrease of magnetic domain width and domain walls spacing velocity, laser treatment causes both formation of additional nucleation centers of magnetization and heterogeneous strain induction near these zones [8].

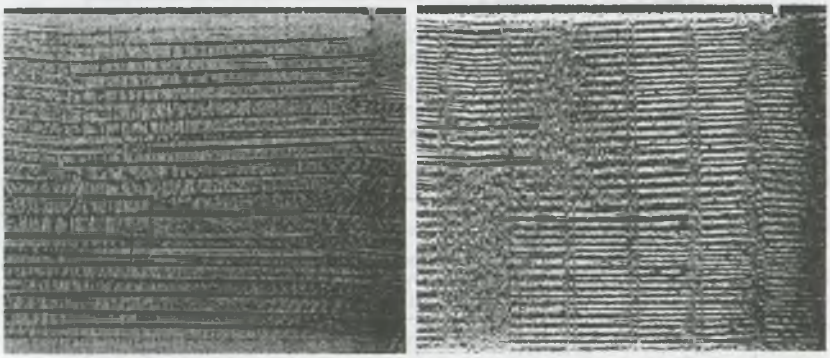

Fig.1. Domain structure of steel before (left) and after (right) of a laser treatment. 2x

Experimental

As the samples for the investigation, we used steel strips (Fe–3%Si alloy) with dimensions of 280x30x0.23–0.30 mm.

The magnetic loss $P_{1.7/50}$ (at an induction of 1.7 T and a frequency of magnetization reversal of 50 Hz) and magnetic induction B_{800} (at field 800 A/m) of electrical steel were measured by apparatus MK-4A. The error of measurements of the magnetic induction was ±1%; that of magnetic losses, ±2%.

The use of an controlled pulse-periodic CO_2– laser with a permanent regeneration of the gas and a simultaneous formation of a continuous region of the laser action over the entire width of the steel ribbon in the optimum regime (specific density of the irradiation energy U = 2.0 J/cm^2; the width of the heat affected zone, 0.2 mm; interzone spacings, 5 mm; the ribbon thickness, 0.30 mm) and the velocity of the ribbon motion equal to 0.5 m/s.

Another treatment of the ribbon steel related to the formation of a magnetically active (tensile) electrical insulating coatings (EICs) Ti–N or modification B–Mg–P coating ~2 μm thick with a temperature expansion coefficient equal to $6 \cdot 10^{-6}$ K^{-1}, which is less than that of steel 13 10^{-6} K^{-1} [9].

Results and their analysis

For reveal of condition optimum of local laser treatment, magnetic losses alteration as the result of repealed (multiple) local laser treatments of grain-oriented steel has been investigated in present work. It was shown that consecutive multiple laser treatment stages carried out by several passes through laser plant result in deterioration of magnetic properties of steel. After grooving the sample bends and the surface subjected to laser irradiation is concave. The magnitudes of tension induced in metal after each stage of treatment were calculated using bend size. The measurements showed that tension level after single laser irradiation is within 0,15 – 0,25 kg/mm^2 and grows up to 0,7–1,0 kg/mm^2 with increasing of number of passes from one to ten. At the same time the diminution of influence of laser treatment on tensile stress in steel occurs.

The influence of tensile stress imparted by insulating coating on laser treatment effect has been studied (Table 1). The influence of local laser treatments on electrical insulating coating effect has been studied (Table 2).

Table 1. Effect of the state of the sample surface on the efficiency of laser treatment

Party	B_{800}, T	$\Delta P_{1\,7/50}$, %	
		EIC	Without EIC
1	1.850	10.3	12.0
2	1.855	8.9	17.0
3	1.865	13.3	22.1
4	1.870	13.7	18.9
5	1.885	14.5	23.3
6	1.905	17.4	27.1

Table 2. Effect of laser treatment on the change in $P_{1.7/50}$ upon the removal of the electrical insulating coating from the sample surface

Party	$\Delta P_{1\,7/50}$, %		B_{800}, T
	without laser treatment	after laser treatment	
1	13.6	3.8	1.880
2	14.4	0.5	1.900
3	7.9	3.3	1.874
4	9.8	1.0	1.870

The optimal operation factors of laser treatment providing highest possible magnetic losses decrease in grain-oriented steel ribbons having different surface condition and magnetization regimes have been determined.

A low-temperature short-term annealing (5 min) at 550 °C was reducing of magnetic losses. but 850 °C in push-type furnace restores the magnetic properties to their initial state.

The lowest level of magnetic losses under the effect of tensile coating and laser treatment is achieved in samples whose crystallographic texture is close to the ideal and optimal cube-on-edge texture (110)[001]

Conclusions

The results of this work showed that both on individual samples and on parties of commercial metal the application of an electrical insulating coating reduces the efficiency of laser treatment. The smaller the values of tensile stresses created by the coating, the more pronounced the effect of laser treatment; i.e., it partly compensates the difference in the so called "magnetic activity" of coatings. The greatest effect of the above actions is achieved in samples with greater degree of perfection of the crystallographic texture.

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References

1. Dragoshanskii Yu.N., Khan E.B., Veksler A.Z., and. Zaikova V.A. Effect of the surface crystallographic orientation of Fe-3%Si monocrystals alloys on their electromagnetic losses. // Fiz. Met.Metalloved. 1972. V 34. № 5. P. 987–994.
2. Dragoshanskii Yu.N., Esina N.K., and Zaikova V.A. Effect of the sharpness of (110)[001] crystallographic texture on the electromagnetic losses in transformer steel.// Fiz. Met. Metalloved. 1978. V 45. № 4. P. 723–728.
3. Dragoshanskii Yu.N., Zaikova V.A., Khan E.B. Effect of crystallographic orientation and elastic deformation on the magnetic losses of Fe-3%Si monocrystals. – Proceedings intern. conf. on magnetism (ICM-73). Moscow: Science. 1974. V 4. P. 518–522.
4. Shimanaka H., Matoba I., Ichida T. et al. Development of a grain-oriented silicon steel with low magnetostriction. – Proceedings of European conf. on soft magnetic materials (SMM-2), Cardiff, 1975. P. 269–274.
5. Sokolov B.K., Gubernatorov V V., Noskov M.M. et al. Thermotreatment of electric steel // Patent RU № 652230. 1979. Bull. № 10.
6. Nozawa T., Matsuo Y., Kobayashi H. et al. Magnetic properties and domain structures in domain refined grain-oriented silicon steel (invited). // J. Appl. Phys. 1988. V 63. № 8. P.2966–2970.
7. Sokolov B.K. and Dragoshanskii Yu.N. Structural barriers and reduction of magnetic losses in grain-oriented steels.// Fiz. Met. Metalloved. 1991. № 1. P. 92–102.
8. Dragoshanskii Yu.N., Karenina L.S., Solovei V.D. et al. Development of stresses in grainoriented steel during laser treatment.//Fiz. Met. Metalloved. 2011. V.112. RU № 2. P.140–145.
9. Khanzina T.A., Bamburov V.G., Dragoshanskii Yu.N. A magnetically active coating on the steel. // Patent RU № 1608243. 1990. Bull. № 43.