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Use of Permanent Magnets for the Linear Asynchronous Motors Braking in Transport

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Abstract: This study describes the linear motor braking model for calculation with the use of permanent magnets. Results of linear motor construction, the choice of permanent magnets and the choice of materials as well as the determination of the braking torque created by the permanent magnets are reported. The method suggested makes possible to work out a magnetic system of braking and to evaluate the developed braking force.

Key words: Linear motor, vehicle, permanent magnet, breaking

INTRODUCTION

The increase in the volume of transport has created a need for the creation of new technological and efficient systems. The efficiency of these systems could depend in a certain manner of the linear motors that is to convert electric energy into mechanical one, with a traction force, allowing the displacement of the locomotive according to a given program on all exploited set speeds. One of the possible alternatives of obtaining such systems of transport is the use of Linear Asynchronous Motors (LAM). Nevertheless when designing such a system, it is necessary to consider the problem of the locomotive braking. This problem can be solved by the traditional methods, used for asynchronous motors.

MODEL CONSIDERED

The aim of this study is to obtain a reliable braking using a simplified permanent magnets model having high energy characteristics. They can be located in the rails and have a link with the secondary elements of the linear asynchronous motor which are fixed on the locomotive (Ikeda *et al*., 1985).

Figure 1 shows the position of the permanent magnets, composed of several elements, used for the braking of the locomotive:

In the drive motor mode, the traction force is produced by the inductor which is on the rails (construction of Guembel of the linear asynchronous motor). In order to obtain the required torque during braking, it is necessary to choose the magnetic system configuration with permanent magnets and make a good choice of their materials and their dimensions (Ikeda *et al*., 1993). For this investigation one considers the construction shown in Fig. 2. The various alternatives of the permanent magnets are examined: In ferrites (21BA210) or many inter-metallic compositions of the type

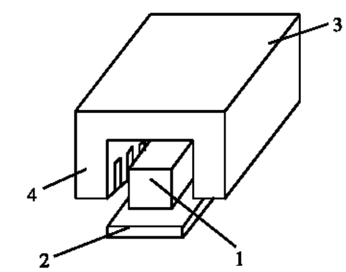

Fig. 1: Position of permanent magnats; 1: permanent magnets; 2: secondary element of the engine; 3: ceiling of the locomotive and 4: soft magnetic material cylinder head

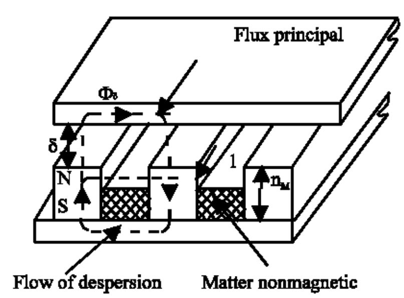

Fig. 2: Magnetic circuit

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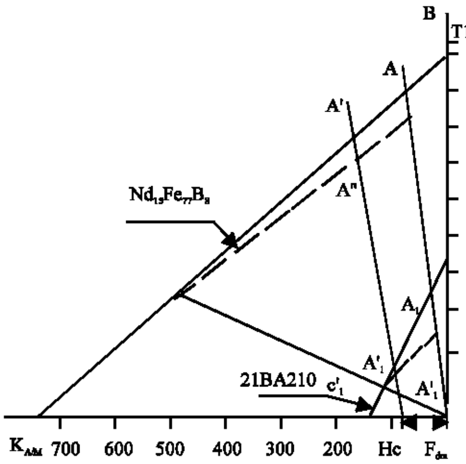

Fig. 3: Curves of demagnetization of the permanent magnets

neodymium-iron-boron (Nd, Fe, B), having a great coercive force Hc. The standard characteristics of demagnetizations of these magnets are shown in Fig. 3.

In the absence of the armature reaction, the properties of the permanent magnets are characterized by the operating point A-for the permanent magnets in NdFeB and by the point A1-for ferrites. It should be noted that the temporary factors of demagnetization do not influence the points of permanent magnet operation which are on the demagnetization characteristics. In order to obtain high inductions in the air-gap (0, 4 - 0, 6 T), the permanent ferrite magnets must be designed in such a manner that they can generate a necessary magnetic flux. This can be obtained by increasing of permanent magnets height (Blease *et al*., 1989).

BACKGROUNDS

To investigate the magnetic circuit presented on Fig. 2, one can present a theoretical model, in which the permanent magnets having a real geometry are replaced by a layer with equivalent currents. Figure 4a shows the spatial distribution of the coercive force Hc(X) in the median section. Let us express Hc (X) according to Fourier series:

$$H_c(x) = \Sigma H_{cv} \times \cos(K_v x) \qquad (1)$$

Where:

K_v = vK.

K = π/τ.

v = Any positive whole number.

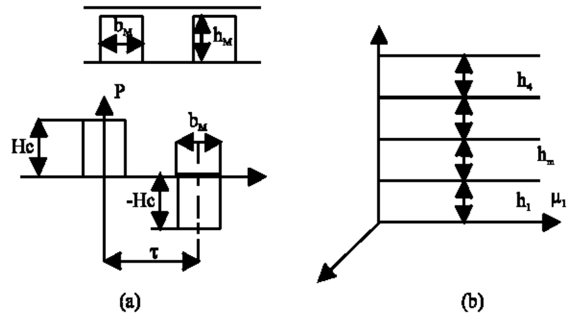

Fig. 4: Model of calculation; (a): Force coercive and (b): Various layers of the model

$$H_{CV} = (4/\pi) \times (1/v) \times H_c \sin[(v b_M/\tau)(\pi/2)] \qquad (2)$$

According to the Maxwell's equation, the linear density of the current, directed along axis Z, is:

$$iM(x) = dH_c\ (x)/dx = \left. \begin{array}{l} \Sigma I_{Mv} \sin(K_v x)\ I_M v = 4Hc/\tau \\ \times \sin[(v b_M/\tau) \times (\pi/2)] \end{array} \right\}$$

For the fundamental harmonic this gives

$$I_M = 4H_c/\tau \times \sin(b_M/\tau \times \tau/2)$$

$$i_M(x) = I_M \sin Kx$$

Thus, a permanent magnet is replaced by a fictitious current in the drivers with an infinitely small section, forming a zone with a permeability $\mu = \rho_M$ having a height h_M and a voluminal density $i_M(x)$. This current is uniformly distributed inside the zone along the axis y (Fig. 4b). The Maxwell's equations for this zone are the following ones (Gilras *et al*., 1977).

$$\nabla^2 A_M = \partial^2 A/\partial^2 + \partial^2 A/\partial y^2 = -\rho_M \times i_M(x) \qquad (4)$$

Where:

A -magnetic potential vector.

Knowing that for the calculation of TF (traction force), it is necessary to determine the magnetic induction in the air-gap produced by the permanent magnets. Let us write the equations of the magnetic potential vector for the following zones: Air-gap with $A\delta$ cylinder head rotorique (supposing that the shorted-circuit coil is open) with A_r and inductor with A_{in}, will be solved at the same time (Freeman *et al*., 1968).

The form of writing equations for these zones is the same one as in Eq. 4, but their right side will be simplified because of the absence of the currents i.e.,

$$\nabla^2 Ai = 0;\ i = \delta, r, U$$

The solution of these equations will have the following form:

For zone I = 1-the cylinder head of the inductor;

$$A_{in} = C_1 \times shyKx \quad (5)$$

for zone I = 2-permanent magnets:

$$A_M = [C_2 xshk\,(y-h_1) + D_2 chK\,(y - h_1) + \rho \times 1_M/K^2[\times sinK \quad (6)$$

for zone I = 3-the air-gap:

$$A_{\grave{a}} = \{C_3 \times sh[K(y-(h_1+h_M))]+D_3 \times ch[K(y-(h_1+h_M))]\} \times sinKx \quad (7)$$

for zone I = 4-the rotor cylinder head:

$$A_r = \{C_4 \times sh[K(y-(h_1+h_M+\delta))]+D_4 \times ch[K(y-(h_1+h_M+\delta))]\} sinKx \quad (8)$$

Here and further one will take h_i (i = 1.. 4) and δ-heights of the corresponding zones (Fig. 4b).

The components of the electromagnetic field Byi and Hxi are obtained according to the derivation of corresponding A_i. By using the boundary conditions (the continuity of the tangential components of the intensity of the magnetic field Hxi and the normal components of magnetic induction Byi), we obtain the system equations:

$$\left.\begin{array}{l} C_1 - C_2 \times \mu_1/ch(Kh_1) = 0 \\ \mu'_1 \times th(Kh_1) C_2 - D_2 = \rho_M \times I_M/K^2 \\ C_2 \times ch(Kh_M)+D_2 \times sh(Kh_M)-\rho C_3 = 0 \\ C_2 \times sh(Kh_M)+D_2 \times ch(Kh_M)-D_3 = \rho_M \times I_M/K^2 \\ C_3 \times \mu'_4 \times ch[K(\delta+h_3)]+D_3 \times \mu' 4 \times sh[K(\delta+h_3)]-C_4 = 0 \\ C_3 \times sh[K(\delta+h_3)]+D_3 \times ch[K(\delta+h_3)]-D_4 = 0 \\ C_4 \times th(Kh_4)+D_4 = 0 \end{array}\right\} \quad (9)$$

Where:
$\mu'_1 = \mu_1/\rho_M$;
$\mu'_4 = \mu_4/\mu_0$;
$\rho' = \rho_M/\mu_0$
relative magnetic permeability of the corresponding zones.

The five system constants of integration can be given either in analytical form according to the resolution of the system equations or in the numerical form by use of standard software for the resolution of the algebraic equations.

According to magnetic laws and by supposing that, $\mu'_1 = \mu' 4 = \infty$ the following expression for induction in the air-gap medium are obtained:

$$B_\delta = 2H_C h_M\{sin[(b_M(\pi/\tau)\times 2)/(\pi \times h_M/\rho_M)]\times \times ch(\pi\delta/2\tau)+(\pi/\mu_0) \times sh(\pi\delta/2\tau)\} \quad (10)$$

In order to determine the torque during braking, we must obtain the expressions for the active component of the electromagnetic power transmitted to the moving rotor. For that, the dental zone with the squirrel-cage (coil is shorted-circuit) and the rotor cylinder head have been replaced by two layers; the dental zone-by an anisotropic layer with a specific resistance equivalent resistance:

$$\rho_{eq} = \rho_z \times \rho'_{enr} \times t_z/(b_{en} \times \rho' en+b_z \times \rho_z) \quad (11)$$

Specific resistances of ñz and ρ'_{en} the tooth and the notch with the equivalent magnetic permeability:

$$\mu_x = \mu_0 \times \mu_z/(\mu_0 b_z+b_{en}\mu_z) \quad (12)$$

$$\mu_y = \mu_z \times b_z/t_z+\mu_0 b_{en}/t \quad (13)$$

and the rotor cylinder head-by an isotropic layer with the following properties:

$$\rho_z = 0,\ \mu_x = \mu_y = \infty$$

The equations of the electromagnetic dental layer field have the following form.

$$(\partial^2 A_M/\partial y)\times\beta^2 A_M = 0 \quad (14)$$

Where:
$\beta = \mu_x/\mu_y \times K^2 + j\mu_x \times \omega_0/\rho_{eq}$
The over all solution is:

$$A_M = (Ce^{\beta y} + De^{-\beta y})e^{-j(\omega t-Kx)}) \quad (15)$$

EXAMPLES

The calculation of the braking relation of force equation Ft = f(V) was carried out for the model of a linear asynchronous motor with the following dimensions:

- Length of the part with the permanent magnets : L = 202,5cm;
- Width of the permanent magnets : B_M = 13,5 cm;
- Height of the permanent magnets : H_M = 15 cm;
- Length of the permanent magnets : L_M = 0,16cm;
- Number of poles : 2p = 10;
- Height of notch of short coil-circuitry : H in = 7 mm;
- Width of notch : B in = 4 mm;
- Width of tooth : bz = 2 mm;
- Air-gap : = 10 mm.

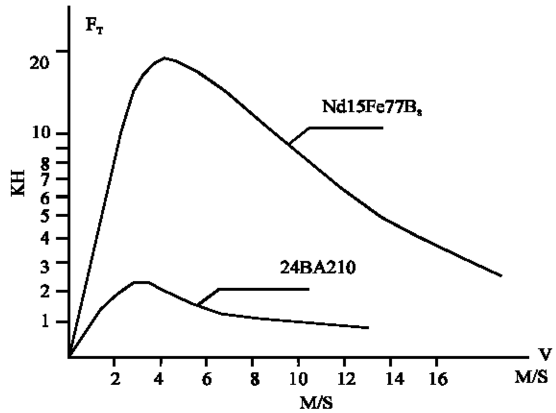

Fig. 5: Curves of the braking forces

The characteristics of the permanent magnets used in this model, are presented in Fig. 3. According to the computation results, the dependence of braking force on speed is obtained (Fig. 5). By comparing the curves, one notes that the force of braking created by the permanent neodymium magnets is 8, 5 times larger than that containing ferrites.

The method suggested makes it possible to work out a magnetic system of braking and to evaluate the developed braking force.

CONCLUSIONS

In order to carry out a reliable braking, it is possible to obtain the resolution of two tasks somewhat different. When resolving the first task, it is necessary to slow down the locomotive on a determined section with Vo speed until speed zero (v = 0) before arriving at the station. At the time of high traveling speed, the transition from drive mode to the braking mode may be flexible to avoid the dynamic shock. When the locomotive travels on a slope, the descent must be carried out with a given speed.

REFERENCES

Blease, J., R. Bhatia and R.M. Pal, 1989. Applying linear motors in handling (Unico Inc). Macine Designe, 26: 91-96.

Freeman, E.M. *et al*., 1968. Travelling waves in induction machines, input impedance and equivalent circuits. Proc. IEEE., 115: 1772-1776.

Gilras, J.F. 1977. Analytical method of calculating the electromagnetic field and power losses in ferromagnetic half space, taking into account saturation and hysteresis. Proc. IEEE., 124: 1098-1104.

Ikeda *et al*., 1985. The behavior of the inductive-levitation-coils in a DC linear motor systems. IEEE Trans. MAG-21, 5: 756-758.

Ikeda *et al*., 1993. The basic consideration of linear motor systems with alignment of permanent magnet poles mounted on vehicles. Proceeding of IEEE/ASME Joint Railroad Conference, Pittsburgh, pp: 109-113.