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Power Factor Analysis of the Linear Motor in Mines

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Abstract

This paper introduces the structure of linear motor in mines. Analyze the power relation of power-AC -linear motor – vibrant machine, based on this, count the power factor; and make mechanical analysis to the vibrancy, get the power factor, which should be: in the precondition of without collision for the top and bottom magnet, do best to decrease the δ_0 to close to ΔX_m (ΔX_m depends on the technique of the vibrant load), make K_δ close to 1 and λ_e close to critical maximum λ_{em}. It is significantly useful to design linear motor.

Index Terms: Linear Motor; Power Factor; Vibration Analysis; Electromagnetic Force; Duty Cycle Analysis

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1. Introduction

When the computer controlling vibration force fundamental frequency equal to the natural frequency that generate electrical and mechanical resonance, the smaller the excitation force may have a greater amplitude. Therefore, linear motor and its AC device can be used for coal mine and replaced large amplitude rotating machinery vibration motor and mechanical transmission device (eccentric wheel and gear, etc.), to cancel friction bearings and mechanical contact, greatly reducing the mechanical and electrical consumption, extend equipment life.

2. Power Relations

As the motor air gap is not only the magnetic field space for mechanical and electrical energy conversion, but also the working air gap for vibration machine reciprocating linear motion, so it is a larger gap width; and since the ratio magnetic energy into mechanical energy is relatively low in a cycle of alternating air-gap width, so power factor is low, coupled with the drive itself, as in the power transfer ratio is less than l, which makes the grid side of the total power factor is lower than the power factor.

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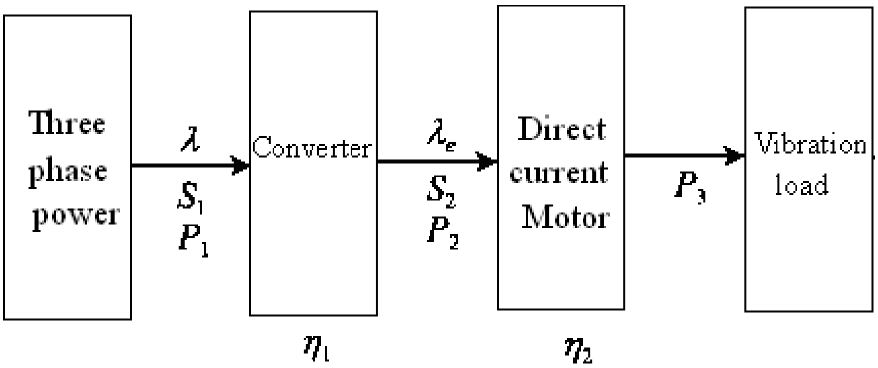

Fig. 1. Power relationship of power - AC devices - linear motors - mechanical vibration

Analysis of linear motor power factor, apparent power converter transmission ratio and overall system power factor, to find the quantitative impact factors of power factor which provide the basis to improve the power factor. From Fig.1 shows the relationship of the every value:

$$\lambda = \frac{P_1}{S_1} = \frac{S_2}{S_1} \cdot \frac{P_2}{\eta_1 \cdot S_2} = \frac{1}{\eta_1} K_S \cdot \lambda_e \tag{1}$$

where λ is the total power on the side of the grid; S_1 、 P_1 are the apparent power and the actual reactive power on grid side; S_2 、 P_2 、 Q_2 are the motor input apparent power and actual reactive power and virtual power.

3. Power Factor

$\eta_1 = \frac{P_2}{P_1}$ is AC converter efficiency. $K_S = \frac{S_2}{S_1}$ is converter apparent power transfer ratio; $\lambda_e = \frac{P_2}{S_2}\cdot$ is motor power factor. Because P_3 is vibration load power, μ_2 is motor efficiency, so

$$\lambda_e = \frac{P_3}{\eta_2 \cdot S_2} \tag{2}$$

So (1) can be as below

$$\lambda = \frac{1}{\eta_1 \eta_2} K_S \cdot \frac{P_3}{S_2} \tag{3}$$

If need to count k_s 、 λ_e and λ, have to count P_3 and S_2

4. Vibration Analyses

By the mechanical analysis shows that the two-mass elastic system for the exciting force in Fig.2 is

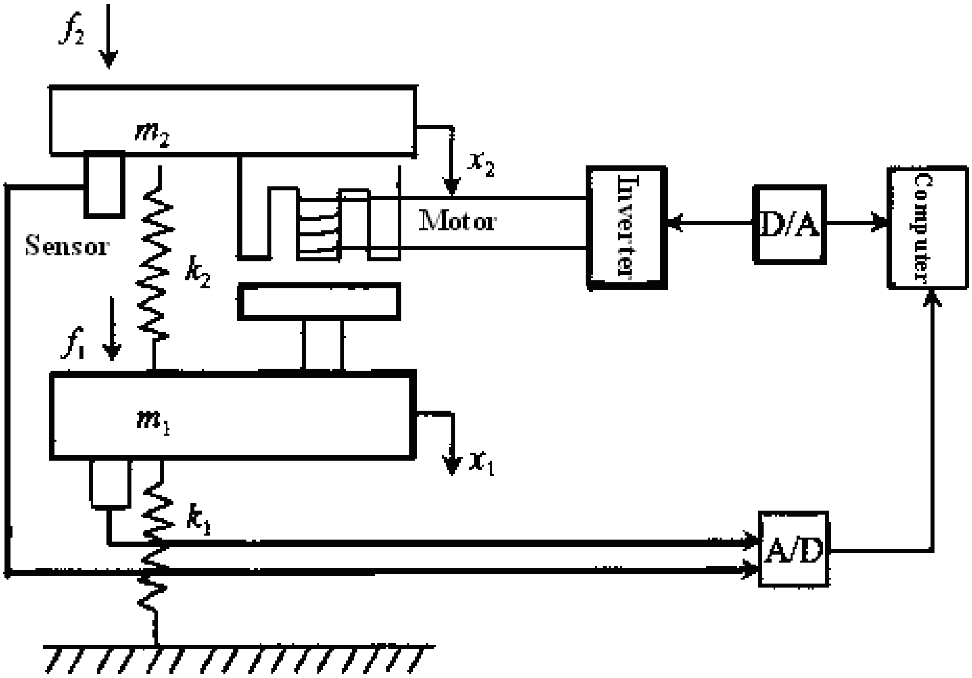

Fig. 2. Computer controlled linear motor drag the double mass sieve system diagram

f_2 、 f_1 are imposed on the upper and lower electromagnetic exciting force screen; k_2 、 k_1 are spring stiffness

m_2 、 m_1 are mass of upper and lower sieve; x_2 、 x_1 are displacement of upper and lower sieve

$$\begin{bmatrix} f_1 \\ f_2 \end{bmatrix} = \begin{bmatrix} F_m \cos \omega t \\ -F_m \sin \omega t \end{bmatrix} \tag{4}$$

Double mass vibration displacement is approximately

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} x_{1m} \cos \omega t \\ -x_{2m} \sin \omega t \end{bmatrix} \tag{5}$$

Motor steady-state gap width of approximately

$$\delta(t) = \delta_0 + \Delta X_m \sin \omega t \tag{6}$$

All kinds expressions of the above, F_m is the amplitude of the electromagnetic exciting force. ω is for the electrical and mechanical resonance angle frequency; x_{1m} 、 x_{2m} are for the double mass displacement amplitude, δ_0 the dynamic level for the position of the gap width of the density, $\Delta x_m = x_{1m} + x_{2m}$ is for the double mass amplitude sum (reduce the dynamic stress passed to the foundation, the system resonance to second-order natural frequency).

5. Analysis of the Electromagnetic Force Duty Cycle

From faraday's law of electromagnetic induction approximately expression can be obtained

$$\phi = \frac{1}{N}\int_0^t u dt = \frac{Um}{N}\int_0^t u^0(t) dt \tag{7}$$

Where N is the number of turns the motor windings,

$$U = U_m u^0(t) \tag{8}$$

U for the converter voltage applied to the motor windings, U_m is the voltage maximum. $u^0(t)$ is

$$u^0(t) = \begin{cases} +1 & 0 \le t \le t_f \\ -1 & t_f < t \le T \end{cases} \tag{9}$$

Where t_f is the turning time for the voltage from positive to negative, $T = \frac{2\pi}{\omega}$ for the electrical and mechanical resonance cycle.

As the role of single-chip microprocessor control, only make the electromagnetic force fundamental frequency component and mechanical natural frequency equal and obtain to electrical and mechanical resonance, the second and above harmonic resonance electromagnetic force are small amplitude which can be neglected effect. F for the electromagnetic suction Fourier expansion, the expression for the fundamental electromagnetic force:

$$F_1 = -F_m \cos \omega t \tag{10}$$

F_m is the maximum value of F_1, get the average power of vibrating machinery

$$F_3 = \frac{1}{2}\omega F_m \Delta X_m \tag{11}$$

If you only consider the motor air gap reluctance while ignoring iron reluctance. By (6) can get reluctance

$$R_\delta = \frac{2\delta}{\mu_0 A} = \frac{2}{\mu_0 A}[\delta_0 + \Delta X_m \sin\omega t] \tag{12}$$

Above formula, A is for the E-type magnet core cross-sectional area. By magnetic Ohm law, consider (7) and (12), we have the current i expression

$$i = \frac{\phi R_\delta}{N} = \frac{2U_m}{N^2 \mu_0 A}[\delta_0 + \Delta X_m \sin\omega t]\int_0^t u^0(t)dt \tag{13}$$

Current valid value is

$$I = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \frac{\omega F_m K_t}{2U_m} \tag{14}$$

Where

$$K_i = \sqrt{\frac{\pi^2}{3}}\delta_0^2 + \sqrt{(\frac{\pi^2}{6} - \frac{1}{4})\Delta X_m^2} \tag{15}$$

Take (14) into the motor apparent power expression $S_2 = U_m I$, obtain

$$S_2 = \frac{1}{2}\omega F_m K_t \tag{16}$$

Take (11), (15) and (16) into (2), obtain

$$\lambda_e = \frac{\Delta X_m}{\eta_2 K_t} = \frac{\Delta X_m}{\sqrt{\frac{\pi^2}{3}\delta_0^2 + (\frac{\pi^2}{6} - \frac{1}{4})\Delta X_m^2}} = \frac{K_\delta}{\eta_2\sqrt{\frac{\pi^2}{3} + (\frac{\pi^2}{6} - \frac{1}{4})K_\delta^2}} \tag{17}$$

Above

$$K_\delta = \frac{\Delta X_m}{\delta_0} \tag{18}$$

K_δ is the amplitude of the motor duty cycle. Fig. 2 shows that upper and lower magnet of the motor critical collision will occur when $\Delta X_m = \delta_0$, so must be $\Delta X_m < \delta_0$, that is $K_\delta < 1$ to avoid collision. $K_\delta = 1$ will be substituted into (17) can be obtained the critical maximum of λ_e

$$\lambda_{em} = 0.462 / \eta_2 \tag{19}$$

Because quick vibration of the large amplitude and random variation of the load (by sieving and conveying the material), in the experiment, K_δ must be small to control the magnet will not crash. The motor magnet will no longer crash when $\delta_0 = 12mm$ through the pre-regulator, so when the motor running normally

$$K_\delta = \frac{\Delta X_m}{\delta_0} = 0.533 \tag{20}$$

6. Conclusions

$\lambda_e = 0.6\lambda_{em}$ by (17) and (19). In order to improve the power factor, must be guaranteed that the motor upper and lower magnet will not collide to make δ_0 as close as possible to the ΔX_m (ΔX_m is dependent on the techniques of vibration load), and make K_δ close to 1, which can make λ_e close to the critical maximum λ_{em}.

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