

THE QUALITY FACTOR OF THE NAVAL M.H.D PROPULSION SYSTEM

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Abstract: A naval propulsion magnetohydrodynamic (M.H.D.) induction is actually a linear induction machine that uses seawater as induced. In seawater occurs an interaction between a magnetic field induced by the progressive currents, resulting an electromagnetic force. This force causes the movement of water, which is discharged from the vessel through a nozzle, thus creating a reactive propellant. Such a propulsion system eliminates the propeller and its annexes reducing energy losses associated with the rotation of water, noise and cavitation.

Keywords: magnetohydrodynamic; propulsion system; magnetic force

1. Introduction

A soundless navigation is essential for a submarine patrol in the maritime area. MHD ship propeller being a linear induction machine, characterized by the size of its effectiveness is called “the quality factor” Q, defined of Laithwaite as the ratio magnetizing reactance and the resistance of the armature:

$$Q = \frac{\omega L_2}{R_2} \quad (1)$$

This definition follows the relationship

$$Q = \frac{2\tau_p \mu_0 f}{\pi \frac{\rho}{\Delta} h} \quad (2)$$

Where:

τ_p is the polar step;

μ_0 -the vacuum permeability;

f - sequence power, resistivity;

ρ , Δ - armature thickness and size of the air gap h.

If an induction machine with the induced seawater, applying relation (1) becomes quite difficult for obvious reasons; therefore, assume a redefinition of energy quality factor considerations. The machine absorbs from the energy source which dissipates in the form of active power and some stores as reactive energy accumulated in the air gap magnetic field.

If we denote W_j , Joule energy dissipation and W_m magnetic field energy in air gap, this report is written as

$$R = \frac{W_j}{W_m} \quad (3)$$

We believe that the electrical machine will be all the more efficiency as muh the ratio of the dissipation and accumulated energy will be higher and we propose to characterize the size MHD thruster naval by so called "energy report" R.

We further demonstrate that the ratio of energy quality factor Q and R expresses the same physical reality. For this, we calculate the energies W_j , respectively W_m . Polyphase windings of the inductor will generate a magnetic field in the airgap, having the character of wave intensity expressed by the

$$H(x, t) = H_m \sin(\omega t - \frac{\pi x}{\tau_p}) \quad (4)$$

This field is moving at synchronous speed:

$$v_s = 2\tau_p f \quad (5)$$

to a designated location. If the armature is moving at speed v, the relative velocity to the induced magnetic field will be:

$$v_r = v_s - v_0 \quad (6)$$

The field gradually travels a distance equal to one polar step during:

$$t_\tau = \frac{\tau_p}{v_s - v} \quad (7)$$

Meanwhile, the induced Joule will dissipate energy expressed by the following relationship:

$$W_j = \int_0^{t_\tau} P_j(x, t) dt \quad (8)$$

Joule power dissipated in an infinitesimal element of length dx will be induced:

$$dP_j = u^2(x, t) dg(x) \quad (9)$$

where u (x,t) is the induced voltage of the field-induced progressively element located at the x-coordinate of a reference point to the end of a pole located at the time t, and g (x) is the conductivity of the armature:

$$g = \frac{1}{R_2} \quad (10)$$

A strip of infinite length induced by low dx, of width equal to the width "a" of the armature conductance will be given by the following relationship:

$$dg = \frac{1}{\rho \frac{a}{\Delta dx}} = \frac{dx}{\frac{\rho}{\Delta} a} \quad (11)$$

The ratio $\frac{\rho}{\Delta} = \rho_s$ is call surface resistance [1, 2]. Induced voltage will be given by Faraday's law of induction:

$$u(x, t) = -\frac{\partial \Phi(x, t)}{\partial t} - Bav_r \quad (12)$$

In a first step is not taken due to the first pulse period, and in this case, the energy dissipated by Joule effect induced in a portion τ_p of the length will be expressed by the equation:

$$W_j = \int_0^{\tau_p} \int_0^{\tau_p} \frac{\mu_o^2 H^2(x, t) a v_r^2}{2 \rho_s} dx dt \quad (13)$$

Substituting in (13) field strength expression and performing integrations, we obtain the relationship:

$$W_j = \frac{\mu_o^2 H_m^2 a \tau_p^2 v_r}{2 \rho_s} \quad (14)$$

Magnetic energy is obtained by integrating the volume of the air gap magnetic field energy density:

$$W_m = \iiint_{V_{int\ refer}} \frac{\mu_o H^2(x, t)}{2} dx dy dz \quad (15)$$

Or:

$$W_m = \frac{\mu_o H_m^2}{2} \int_0^a dy \int_0^h dz \int_0^{\tau_p} \sin^2(\omega t - \frac{\pi x}{\tau_p}) dx \quad (16)$$

After integration we get:

$$W_m = \frac{\mu_o H_m^2 a \tau_p h}{4} \quad (17)$$

The value of ratio R became:

$$R = \frac{2 \mu_o \tau_p v_r}{\rho_s h} \quad (18)$$

If we introduce the sliding,

$$s = \frac{v_s - v}{v_s} = \frac{v_r}{v_s} \quad (19)$$

and given expression synchronous speed (5) one gets

$$R = 2 \pi s \frac{2 \mu_o f \tau_p^2}{\pi \rho_s h} = 2 \pi s \frac{2 \mu_o f \tau_p^2}{\pi \frac{\rho}{\Delta} h} \quad (20)$$

During starting s = 1 and at the moment:

$$\frac{R}{Q} = 2 \pi \quad (21)$$

(Actually, the relationship 2 was deducted all at boot time).

The fact that R/Q is a dimensionless constant, makes us say that both R and Q express the same physical reality: linear induction machine efficiency. That $R \neq 0$ may be due to the fact that it took into account the induced voltage pulse. So size R can be used instead of Q having the advantage of a clear physical sense and a simple method of calculation.

If the MHD ship propeller induction phenomena is complicated by the fact that the velocity is not uniform across the flow passage, it having a maximum value and zero axis in contact with the channel walls. To apply equation (3) if a propeller sea water, must be calculated using equations Maxwell - Hertz W_j and W_m energies and also taking into account hydrodynamic processes expressed by equation Navier - Stokes. The resulting differential equations systems are very complex and can only be solved using simplifying assumptions. Such a calculation is presented in [3], but the results could not be verified experimentally. We are proposing an alternative method simpler calculation that leads to similar conclusions. The slipping s can not be defined only locally: it will be a function of the form:

$$s(x, z) = \frac{v_s - v(x, z)}{v_s} = 1 - \frac{v(x, z)}{v_s} \quad (22)$$

In the vicinity of the free surface MHD channel axis speed has maximum value v_s : here the slipping s_0 is:

$$s_0 = \frac{v_s - v_{0\max}}{v_s} = 1 - \frac{v_{0\max}}{v_s} \quad (23)$$

The ratio R of energy can be expressed using the average value of slip:

$$\bar{s} = \frac{1}{2ah} \int_{-a}^{+a} \int_0^h s(x, z) dx dz \quad (24)$$

Velocity value of the channel, depending on maximum speed is calculated in [4].

$$v(x, z) = v_{0\max} \frac{1 - \frac{chHx}{chHa} \frac{z^2}{h^2}}{1 - \frac{1}{chHa}} \quad (25)$$

Ha is Hartman number:

$$Ha = B_0 a \sqrt{\frac{\tau}{\eta}} \quad (26)$$

B_0 is the effective value of the magnetic field:

$$B_0 = \frac{B_m}{\sqrt{2}} = \frac{\mu_0 H_m}{\sqrt{2}} \quad (27)$$

$$\tau = \frac{1}{\rho} \quad \text{conductivity environment (for}$$

seawater $\tau = 5 \Omega^{-1} m^{-1}$) and η is the dynamic viscosity. The factor $\frac{z^2}{h^2}$ in (25) occurred because in [4] was adopted simplifying assumption that the distribution of velocities in depth is very little influenced by the magnetic field.

$$\bar{s} = \frac{1}{3} \left[2 + s_0 \left(1 - \frac{thHa}{Ha} \right) \right] \quad (28)$$

Substituting in (24) the sliding expressed with the relation (25) is obtained:

CONCLUSION

1. The quality factor of a linear induction machine can be expressed using the energy ratio R, defined as the ratio of the active energy and the energy dissipated in the magnetic field induced inside.
2. An MHD ship propeller can be effective efficiency only if the product $\tau_p^2 f$ is often higher than 10^7 then a classic linear motor. On a classic motor $\tau_p \approx 10^{-2}$ m and $f = 50$ Hz. A naval propulsion MHD induction must be designed so that $\tau_p \approx 1$ m and $f = 50$ kHz. Such sizing brings some technical difficulties can be resolved.

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$$R = \frac{2\pi}{3} \frac{2\mu_0 f \tau_p^2}{\pi \frac{\rho}{h} \Delta} \left[2 + s_0 \left(1 - \frac{thHa}{Ha} \right) \right] \quad (29)$$

This relationship certainly is not perfectly correct as far as was deduced using some simplifying assumptions, but gives some information about the phenomena produced by the unevenness of flow velocity in the channel.

A first information that follows is that the flow rate of the channel axis is equal to synchronous speed the s_0 became zero; R does not reduce as an solid induced machine case. In this case, although the channel axis disappear inductive processes, they still present elsewhere. The forces that are generated will be zero, causing water training. Energy R ratio value is determined mainly by the front bracket factor in equation (29) that increases the polar and linear quadratic step frequency. MHD thruster handicap essential to naval induction resistivity comes from the large amount of sea water. E.g:

$$\frac{\rho_{seawater}}{\rho_{copper}} \cong 10^7 \quad (30)$$

In order that the energy from the engine MHD R have the same order of magnitude as a copper-induced motor, it is necessary to be satisfied with the following relation:

$$\frac{(\tau_p^2 f)_{seawater}}{(\tau_p^2 f)_{copper}} \cong 10^7 \quad (31)$$

Equation (31) explains that experiments with classical principles inductors designed after the armature has been replaced with a metal pipe with sea water, no conclusive results.

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