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ON THE MAGNETIC NOISE AT ROTARY ELECTRIC MACHINES. PART II

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Abstract. In the paper it is studied the magnetic noise which has its origin in the action of Maxwell forces of traction, which appear in the air gap of rotary electric machines. It is put in evidence the fact that under the action of the alternative forces, which have, in the air gap, a periodic distribution in relation to the space and time, the stator and rotor of rotary electric machines execute forced oscillations of extension and flexion. The different cases of resonance are approached.

1. INTRODUCTION

In the first part of the work, it was studied the magnetic noise which has its origin in the action of Maxwell forces of traction, which appear in the air gap of machine. Under the action of the alternative forces, which have, in the air gap, a periodic distribution in relation to the space and time, the stator and rotor execute forced oscillations of extension and flexion. Practically, the radial efforts are the only ones which produce noise, the other ones being taken into account in special cases, only [2].

In the second part of the work, there are studied the different cases of resonance.

2. CASE OF RESONANCE

The proper frequency of resonance of the stack of sheets in stator, for $r \geq 2,$ can be calculated with the relation [1]

$$f_p = \frac{1}{2\sqrt{3}} \frac{h}{R_{js}} \frac{r(r^2-1)}{\sqrt{r^2+1}} f_{p0}, \qquad (1)$$

where, in addition to the notations in figure 1, there are used the notations as fallows:

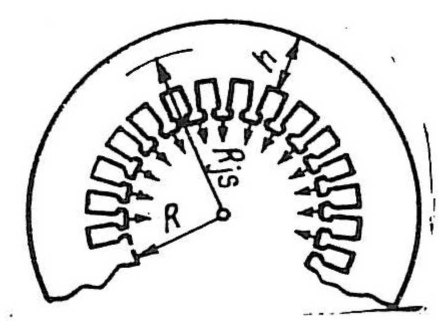

Fig. 1. Signification of notations in formula (1)

- f_{p0} - proper frequency of resonance for $r = 0,$ having the value

$$f_{p0} = \frac{83750}{R_{js}\sqrt{\Delta}}; \tag{2}$$

- Δ - ratio of the mass of collar plate, over the total mass of stack of sheets of the stator.

These proper frequencies, f_p, determined by calculus, in general increase in relation to the real proper frequencies, when the height of collar plate of the stator and the order number r of the mechanical oscillations, also, increase; therefore, the real field of resonance appears for frequencies, smaller than the calculated ones [1].

The number of waves r ($2r$ nodes) at the periphery of the deformed stack of sheets (figure 2), indicates, also, the order of the proper oscillation; at the circle of diameter D, the wave length is

$$\lambda_r = \frac{\pi D}{r}. \tag{3}$$

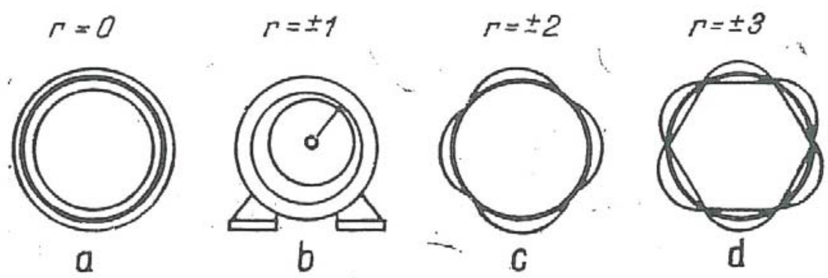

Fig. 2. Oscillation shapes of stator, respectively of rotor

At a certain oscillation, the dynamic deviation of the carcass parts, comprised between two nodes, is obtained by multiplying the static deviation, given by the relation [2],

$$X_{rstat} = 12\frac{R}{E(\frac{h}{R_{js}})^3(r^2-1)^2}F_r, \tag{4}$$

with the increment factor, due to resonance [2],

$$\zeta_r = \frac{1}{\left|1-(\frac{f_r}{f_p})^2\right|}. \tag{5}$$

At the big synchronous generators, with the exterior diameter round about of 8 m, the proper frequencies, corresponding to the order numbers $r = 4,5,6,$ are situated in the domain of $2f$.

The mechanical waves, produced by the harmonics b_ν, present in the case of sum frequencies, after the relation

$$f_r = f_{i1} \pm f_{i2}, \tag{6}$$

the value $|r_s| = 2p,$ whose influence, at these machines, must be considered.

For the short-circuited rotors, for the order numbers, it results the values [2]

$$r_{1\mu} = Z_2 |g_2|^{\pm 2p(S)}_{+0(D)}, \tag{7}$$

whose corresponding frequencies are:

$$|f_r| = 2f\,[\frac{Z_2|g_2|}{2p}(1-s)^{\pm 1}_{+0}]^{(S)}_{(D)}. \tag{8}$$

This kind of writing shows that, for example, at the sum *S*, it is valid $\pm 2p,$ and at the difference *D*, it is valid +0.

3. COMMUNE ACTION OF FIELD WAVES OF STATOR AND ROTOR

The last group of products of field waves in the equation

$$b^2 = b_1^2 + 2(\sum_{\nu} b_1 b_\nu + \sum_{\mu} b_1 b_\mu) + \sum_{\nu} b_\nu^2 + \sum_{\mu} b_\mu^2 + 2(\sum_{\nu_1 \prec \nu_2} b_{\nu_1} b_{\nu_2} + \sum_{\mu_1 \prec \mu_2} b_{\mu_1} b_{\mu_2} + \sum_{\nu_\mu} b_\nu b_\mu). \tag{9}$$

comprises the commune action of the field waves of stator and rotor, $b_\nu b_\mu$.

For the cage rotor, the values $r_{\nu\mu}$ are calculated with the relation [1]

$$r_{\nu\mu} = Z_2 g_2 + p(\pm 2mg^{\pm 2}_{1+0})^{(S)}_{(D)}. \tag{10}$$

From this relation, it results that, for diametral winding in stator and even slot number in rotor, $Z_2,$ only mechanical waves with even order numbers *r* appear. The corresponding acoustic frequencies f_r are calculated with the formula (8) and, in general, they are situated in the domain of dangerous frequencies.

The equation (10) shows that there are arbitrary combinations of field waves, described by g_1 and $g_2,$ which produce mechanical waves with order numbers $|r| \leq r_{max}.$

If the relation (10) is explicitly written, in relation to $g_1,$ i.e.

$$g_1 = \Phi(g_2, r, Z_2, p, n), \tag{11}$$

for a certain machine, $Z_2,$ *p* and *n* are known. After the equation (8), in the case of the difference *D*, it can be written

$$|f_{rD}| = 2f\,\frac{Z_2}{2p}(1-s)|g_2| \tag{12}$$

and, from here, it can be obtained the limit values for $g_2,$ from the condition for the limits of frequency [1],

$$g_{2\,max} = [\frac{\frac{f_{min}}{2f}+1}{\frac{Z_2}{2p}(1-s)}], \tag{13}$$

respectively

$$g_{2\,min} = [\frac{\frac{f_{max}}{2f}-1}{\frac{Z_2}{2p}(1-s)}]_{+0}^{+1}, \tag{14}$$

where:
- f_{min} - imposed inferior limit frequency;
- f_{max} - imposed superior limit frequency.

4. CONCLUSIONS

The relations (13) and (14) show that, at the formation of mechanical waves, in a certain domain of frequencies, field waves of rotor take part, with an order number μ, as bigger as the sliding is bigger (g_2 increases with the decreasing of sliding).

It is also possible, to indicate limit values for g_1, in accordance to the relation (11), taking $r_{max} = 12$ and the values of g_2, comprised between the limits, given by the relations (13) and (14).

All these conclusions are valid for the rotary electric machines that are unsaturated and symmetric, from the magnetic and mechanical point of view.

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