3. On the Torque Acting on the Rotor Rotating in the Rotating Magnetic Field.

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In the high speed rotation by rotating magnetic field [1], the torque due to the interaction between the magnetic field and the induced eddy current in the rotor was theoretically calculated from the Maxwell equations. We used a cylindrical coodinates (ρ, ϕ, z) fixed with the rotor, in which the rotating axis was chosen as the z-axis. It was assumed that the rotor was an infinitely long metal rod rotatiog with an angular velocity ω_r about its axis, in the rotating magnetic field (angular velocitp ω_m) which might be considered to be composed of two alternating components differing 90° each other in phase.

At first we must notice the relative angular velocity or slip speed ω_s and the z-component of the vector potential. The general solution of the vector potential could then be obtained easily from the well-known eddy currents equation. If we consider that this general solution might reduce to the vector potential of the external fields when ρ is greater than the radius of the rotor a, the total current density in the z-direction and the magnetic induction in the rotor can be calculated under the boundary condition at $\rho=a$.

The torque T per unit length acting on the rotor is then given as

$$T=4\mu a^2 B_0^2 f(x) \qquad \text{(in e. m. u.)}$$

$$f(x)=\frac{\mathrm{ber}_0 x\,\mathrm{ber}'_0 x+\mathrm{bei}_0 x\,\mathrm{ber}'_0 x}{x\{[(\mu+1)\mathrm{ber}_0 x-(\mu-1)\mathrm{ber}_2 x]^2+[(\mu+1)\mathrm{bei}_0 x-(\mu-1)\mathrm{bei}_2 x]^2\}}$$

where $x=\sqrt{p}\,a$, $p=\frac{4\pi\mu\omega_s}{\sigma}$, B_0: applied external magneticfield (r. m. s.), μ: permeability, σ: specific resistivity, $\omega_s=\omega_m-\omega_r$, and $\omega_s=2\pi f_s$. Numerical results are shown in the next table.

Table Torque T (relative value)

slip freq. f_s	0	100	150	200	500	1,000	2,000	5,000	10,000	100,000
for Duralumin	0	0.182	0.190	0.180	0.122	0.092	0.067	0.044	0.029	0.001
for Iron	0	0.090	0.104	0.108	0.076	0.050	0.031	0.021	0.013	0.004

It is seen that the torque has a maximum at 150 slip freq/sec for a Duralumin rotor, $a=1.5$ cm, $\mu=1$, $\sigma=3.4\times10^3$, and also at 200 slip freq/sec for an iron rotor, $a=0.15$cm, $\mu=100$, $\sigma=10^4$.

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