Appendix A

Parseval's Method of Fourier Transform applicable for Linear induction motor

The following symbols are defined for the different parameters of the SLIM as shown in Fig. 6.1:

L: Primary stator length

w: Half width of Primary iron (stator core)

d: Half width of Secondary conductor plate

$a-b$: Air gap

$b-c$: Thickness of secondary conductive sheet

c: Thickness of secondary backiron

J_m: Primary current density

P: Number of poles

τ: Pole pitch

σ_1: Conductivity of iron

σ_2: Conductivity of secondary conductive material

μ_0: Permeability of air

μ_1: Permeability of iron

μ_2: Permeability of secondary conductive material

n: order of harmonic representing transverse variation of field by means of Fourier series

ξ: The Fourier space Transform counterpart of x-coordinate, or wave number in per meters

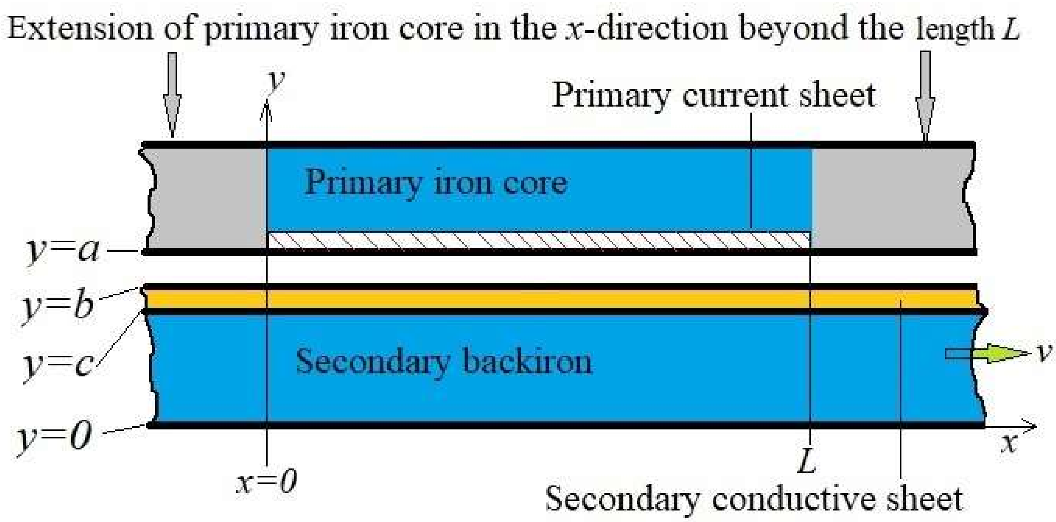

Fig. 6.1 Model of single-sided linear induction motor

[5]

Then, the thrust of the SLIM is given by:

$$F_t = \frac{\mu_3 J_m^2}{\pi} \int_{-\infty}^{\infty} \frac{1 - cos(\xi + k)L}{\xi(\xi + k)^2} \sum_n c_n \frac{\eta_n}{\lambda_n} \Im \left[\frac{W_n(\xi, a)}{K_n(\xi)} \right] \sin \lambda_n w \, d\xi \tag{6.1}$$

where,

$$J_m = \frac{\sqrt{2} \times \text{Slots} \times \text{Cond. per slot} \times \text{Current}}{L} \tag{6.2}$$

$$k = \frac{\pi}{\tau} \quad Wave\ constant,\ per\ meter \tag{6.3}$$

$$\lambda_n = \frac{n\pi}{2d},\ n = 1, 3, 5... \tag{6.4}$$

$$c_n = \frac{2 \sin \lambda_n w}{\lambda_n d} \tag{6.5}$$

$$\eta_n = \sqrt{\xi^2 + \lambda_n^2} \tag{6.6}$$

$$\chi_n = \sqrt{\xi^2 + \lambda_n^2 + j\omega\mu_1\sigma_1 + j\xi v\mu_1\sigma_1} \tag{6.7}$$

$$\gamma_n = \sqrt{\xi^2 + \lambda_n^2 + j\omega\mu_2\sigma_2 + j\xi v\mu_2\sigma_2} \tag{6.8}$$

λ_n is the index number of the Fourier series in the transverse direction.

c_n is the coefficient of the Fourier series expansion of the rectangle, which represents the primary current in the transverse direction.

η_n, χ_n and γ_n are the Fourier layer indices of air, backiron and secondary sheet respectively.

$$\begin{aligned}K_n(\xi) = &\cosh\eta_n(a-b)\cosh\gamma_n(b-c)\left\{1+\frac{\mu_0}{\mu_1}\frac{\chi_n}{\eta_n}\tanh\chi_n c\right\}\\ &+\sinh\eta_n(a-b)\cosh\gamma_n(b-c)\left\{1+\frac{\mu_1}{\mu_0}\frac{\eta_n}{\chi_n}\tanh\chi_n c\right\}\\ &+\cosh\eta_n(a-b)\sinh\gamma_n(b-c)\left\{\frac{\mu_0}{\mu_2}\frac{\gamma_n}{\eta_n}+\frac{\mu_1}{\mu_2}\frac{\gamma_n}{\chi_n}\tanh\chi_n c\right\}\\ &+\sinh\eta_n(a-b)\sinh\gamma_n(b-c)\left\{\frac{\mu_2}{\mu_0}\frac{\eta_n}{\gamma_n}+\frac{\mu_2}{\mu_1}\frac{\chi_n}{\gamma_n}\tanh\chi_n c\right\}\end{aligned} \tag{6.9}$$

$$\begin{aligned}W_n(\xi,y) = &\cosh\eta_n(y-b)\cosh\gamma_n(b-c)\left\{1+\frac{\mu_1}{\mu_0}\frac{\eta_n}{\chi_n}\tanh\chi_n c\right\}\\ &+\sinh\eta_n(y-b)\cosh\gamma_n(b-c)\left\{1+\frac{\mu_0}{\mu_1}\frac{\chi_n}{\eta_n}\tanh\chi_n c\right\}\\ &+\cosh\eta_n(y-b)\sinh\gamma_n(b-c)\left\{\frac{\mu_2}{\mu_0}\frac{\eta_n}{\gamma_n}+\frac{\mu_2}{\mu_1}\frac{\chi_n}{\gamma_n}\tanh\chi_n c\right\}\\ &+\sinh\eta_n(y-b)\sinh\gamma_n(b-c)\left\{\frac{\mu_0}{\mu_2}\frac{\gamma_n}{\eta_n}+\frac{\mu_1}{\mu_2}\frac{\gamma_n}{\chi_n}\tanh\chi_n c\right\}\end{aligned} \tag{6.10}$$

Also, the total attracting force is given by:

$$F_p = F_{px} + F_{py} + F_{pz} \tag{6.11}$$

where,

$$F_{px} = -\frac{\mu_0 J_m^2 d}{4\pi}\sum_{n=1}^{\infty} c_n^2 \int_{-\infty}^{\infty} \frac{1-\cos\xi L}{(\xi+k)^2}\, d\xi \tag{6.12}$$

$$
\begin{aligned}
F_{py} =& \frac{\mu_0 J_m^2 d}{4\pi} \int_{-\infty}^{\infty} \sum_{n=1}^{\infty} c_n^2 \left[\frac{1-\cos\xi L}{\xi^2(\xi+k)^2} \eta_n^2 \left| \frac{W_n(\xi,y)}{K_n(\xi)} \right|^2 \right. \\
&+ \frac{1-\cos\xi L}{\xi^2} \frac{\lambda_n^2}{k^2} \left| \frac{W_n(0,y)}{K_n(0)} \right|^2 \\
&\left. - \frac{\eta_n \lambda_n}{k} \frac{2(1-\cos\xi L)}{\xi^2(\xi+k)} \Im \left\{ \frac{W_n(\xi,y)}{K_n(\xi)} \frac{W_n(0,y)}{K_n(0)} \right\} \right] d\xi
\end{aligned}
\tag{6.13}
$$

$$
F_{pz} = -\frac{\mu_0 J_m^2 d}{4\pi} \sum_{n=1}^{\infty} \lambda_n^2 c_n^2 \int_{-\infty}^{\infty} \left(\frac{1-\cos\xi L}{\xi^2(\xi+k)^2} \right) \left(+ \frac{1-\cos\xi L}{\xi^2 k^2} + \frac{2(1-\cos\xi L)}{k\xi^2(\xi+k)} \right) d\xi
\tag{6.14}
$$

The method of performing the numerical integration can be found in [62].

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List of Publications

IN REFERRED AND PEER-REVIEWED JOURNALS

1. **L. B. Xaxa**, A. Kumar, R. K. Srivastava, R. K. Saket and B. Khan, "Design Aspects and Thermal Characteristics of Single-Sided Linear Induction Motor for Electromagnetic Launch Application," in IEEE Access, vol. 10, pp. 72239-72252, 2022, doi: 10.1109/ACCESS.2022.3188673.

2. **Lovesh B. Xaxa**, R.K. Srivastava and R.K. Saket, "Effects of Joints in Reaction Rail and Proximity of Ferromagnetic Material on the Thrust of Linear Induction Motor," in GMSARN International Journal.

3. **Lovesh B. Xaxa**, Sachin Kumar, Sunil Singh, R.K. Srivastava, R.K. Saket "Synchronous Generator Abnormality and Fault Analysis" in J. Electrical Systems 19-1 (2023), pp. 98-110.

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2. A. Kumar, H. Anand, **L. B. Xaxa**, K. Gupta, A. Kumar and R. K. Srivastava, "Way-side Hyper-loop System using Double Sided Linear Induction Motor," 2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT), Male, Maldives, 2023, pp. 1-5, doi: 10.1109/GlobConHT56829.2023.10087437.

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