Chapter 6

Conclusions and Future Scopes

6.1 Conclusions

Designing an SLIM for EM launch application involves shaping its thrust-velocity curve to be inverse-linear which is in itself a challenging task. By reducing the secondary conductive sheet thickness and increasing the air clearance, the characteristic seems to become closer to what is desired but too thin of the secondary sheet might result in its melting. Also, larger air gap means more magnetizing current drawn from the supply to deliver the same power output, implying increased losses and hence temperature rise. German silver (non-magnetic grade) has been identified as the most suitable material for the secondary conductive sheet of the SLIM for EMLS because its thrust-velocity curve is close to inverse linear relationship (stable region of operation of LIM), which significantly reduces the accelerating time during the launch. Further, alternative materials such as zirconium-copper alloy can be opted for the primary winding wire and secondary conductor which have higher melting points and can withstand greater thermal stresses.

The study reports constant current and frequency design of EMLS. It has been observed that constant thrust versus speed of launch for the same exit velocity yields lesser thrust requirements. However, it requires the Variable Voltage Variable Frequency (VVVF) technology for its operation and also, the launch is a bit delayed. Furthermore, the mechanical time constant of such energy machines are comparable to its electrical time constant, rendering VFD control difficult to implement.

The study indicates the need of either increasing the supply frequency or going for a multi-section stator, with each section having progressively increasing frequency by employing Rising Frequency Generator (RFG). A variable pole pitch LIM is also suggested with compensating windings which overcomes the design challenge. These machines are subjected to very high voltage 3-phase pulse power. The presence of unstable zone (positive slope) in the transient thrust-speed char- acteristics, oscillations in thrust may occur during the launch.

The 2-D FEM analysis gives a fairly good picture of the effects of joints in the reaction rail of SLIM. The eddy current patterns in the secondary sheet and back-iron along with flux distribution help in understanding these effects. It can be inferred that the presence of back-iron makes the forces swell when a joint in the secondary comes under the primary. These joints in reaction rail are having comparatively greater significance under dynamic condition as compared to standstill condition. 2- Dimensional FEM simulation gives fairly approximate results as far as thrust is concerned, but the results for normal force aren't even close to approximation. When machine is being used as a short distance thruster or is at the terminus of transport utility, care must be taken to completely avoid any such joints in the reaction rail. It is suggested that periodic monitoring of the reaction rail should be carried out for the presence of jutted iron in the case of cage type secondary and for the electrical continuity between the jointed sheets in the case of composite or plain secondary.

6.2 Future Work

For the advancement of the present work:

- The experimental assessment of Thermal aspects of this research work is proposed for the future by envisaging heat sensors to be employed for recording the surface temperatures of the stator and coils of the prototype SLIM.

- The analysis of the transient current and dynamic thrust to assess the stability of the launch is being undertaken.

- In the present work, double layer, full pitch winding has been assumed. Several other configurations are also being envisaged like single layer winding and tooth (polar) windings for obtaining optimum operation.

- Further studies involve the EMI/EMC aspects of such machines.

- A comprehensive 3-D simulation and analytical solution is being envisioned and undertaken to get the accurate picture of the effect of joints.

- Also, a 3-D simulation of LIM with cage secondary with jutted out iron from the secondary in the air-gap will reveal clearer scenario of the effects than that obtained in this paper.

  Further works being contemplated to be undertaken for future research endeavors include:

- The derivation of analytical equations for end effect braking force, efficiency, power factor and output thrust as well as multi-objective optimization to maximize efficiency and power factor and to reduce end effect braking force and primary weight.

- Comparison of performances and equivalent circuit parameters of the LPMSM and LIM designs.

- To study VPPLIM dynamic characteristics using ANSYS Maxwell.

- Linear induction launcher (LIL) and Linear Reluctance motor based launching systems.

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