Abstract

The existing fuel based launching methods have reached a saturation point where they cannot meet modern launcher requirements such as higher projectile velocity and specific thrust. Comparatively, the launcher costs and simplification of the equipment drastically improves with linear electromagnetic (EM) launchers, which enables an object to be propelled within a minuscule time attaining a certain high velocity using EM force. It finds its application in national defense, traffic and aerospace owing to its advantages which include simple structure, recyclability, controllability, etc.

Once considered insurmountable, the technical barriers have yielded to focused theoretical, computational, and experimental research and several countries all over the world have taken up the challenge of developing and understanding the art and science of EM launch and launchers. Stationary long-primary single-sided LIMs (SLIMs) offer higher force density and acceleration due to its secondary conductive sheet (mover) being lightweight as compared to other types of LIMs which is suited for EM launch application. Also, there is no requirement of sliding contacts for current collection. Additionally, when combined with high temperature superconducting magnetic levitation system, long-primary SLIM would operate without any friction loss and guidance control system.

This thesis presents the design aspects of SLIM for Electromagnetic launchers. It is designed to accelerate a 50 kg mass through a distance of 3 meters within a minuscule time to an exit velocity of 50 m/s. A mathematical model of the EM launch system (EMLS) is developed and a study of the motor's parametric variation based on the launching requirement has been performed. Its performance characteristics are obtained using 3D FEM and verified analytically using Parseval's method for constant current drive. The FEM, analytical and experimental verification of the thrust characteristics of different secondary conductive sheet materials namely, aluminum, Beryllium copper and German

silver shows that, the latter exhibits superior characteristics than the former two, 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. The designed SLIM is assessed for and satisfies the performance specifications as required for launching.

The electrical windings are the heart of any electrical machine. It converts three-phase pulse power into active propulsion for electromagnetic thruster / launching application. These are essentially an energy machines which are ON only for few half cycles. The large power for momentarily smaller duration of time is provided by special power supplies which are meant for such applications. The thrust-speed characteristics of SLIM and torque-speed characteristics of a rotary motor are almost similar in nature. The machines having unstable portion of toque-speed or thrust-speed characteristics will take a longer time for achieving the desired speed, which is aggravated in the presence of severe oscillations during starting period. Here four different types of windings have been studied from the perspective of SLIM for thruster or launcher applications. Most of the permanent magnet brushless synchronous motor (PMBLSM) have tooth windings. However, in case of LIM such types of windings have not been reported. Concentrated tooth winding configuration can be more efficient for a segmented stator since transition effects between segments can be neglected. Such winding layout is easier to manufacture and locally repair than distributed windings and has shorter end-windings or end turns and lesser copper consumptions leading to reduced Joule losses. Double-layer windings were also considered since they generally produce a more sinusoidal back-emf waveform.

Further, effects of Joints in reaction rail and back-iron and proximity of ferromagnetic material on the thrust of LIM is investigated. In LIM thrust production is affected due to local conditions of reaction rail. Any break in the path of eddy currents affects the performance of LIM. In case of composite sheet secondary, a continuous conducting sheet or a continuous back-iron is not ensured unless proper electrical continuities of

the respective materials are maintained throughout the path of travel. The preparation of reaction rail is done with joining longitudinal pieces of sheets of conducting material and that of ferromagnetic material both of proper sizes and shapes. The prepared reaction rail may offer electrical discontinuities due to improper joints at certain regular distances. Such a discontinuity abruptly breaks the path of the induced eddy currents and thereby momentarily generating thrust ripples at the instant when LIM primary moves over it leading to vibrations. Furthermore, the presence of ferromagnetic material in the entrefer changes the eddy current pattern in conducting sheet and thereby affects the force production. This thesis also discusses the effect of a single joint in secondary conducting sheet and back iron on thrust production as well as the effect of presence of thin ferromagnetic strip in clearances of LIM. The standstill and dynamic analysis is obtained by 2D-FEM simulation on ANSYS Maxwell software. The results can be further used for finding a better alternative of reaction rail. While the joints may pose some discomfort, the presence of ferromagnetic jut doesn't seem to be a nuisance.

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