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Finite element analysis of the cogging force in the linear synchronous motor array for the Thirty Meter Telescope

Gabriele Gilardi [a], Kei Szeto [b], Steve Huard [c], Edward J. Park [a,d,*]

[a] Department of Mechanical Engineering, University of Victoria, PO Box 3055 STN CSC, Victoria, BC, Canada V8W 3P6
[b] Dominion Astrophysical Observatory, NRC Herzberg Institute of Astrophysics, 5071 West Saanich Rd., Victoria, BC, Canada V9E 2E7
[c] Parker Hannifin Corp., Electromechanical Automation, NA, 550 Business Park Drive, Rohnert Park, CA 94928, United States
[d] Mechatronic Systems Engineering, School of Engineering Science, Simon Fraser University, 250-13450 102nd Avenue, Surrey, BC, Canada V3T 0A3

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ABSTRACT

In this paper, a finite element analysis of the cogging force generated by an array of linear synchronous motors (LSM) moving on a curvilinear track is presented. This system is under consideration as the driving system for the two main axes of the proposed Thirty Meter Telescope that will be built in Mauna Kea, Hawaii. The main objective of this work is the quantification of the effects of the curvilinear track of LSM arrays on the cogging force. The finite element analysis is carried out using planar cross sections, and the results found are used to find an approximate solution for the three-dimensional model. The results show that the presence of the curvilinear–configured track increases the cogging force of a single LSM significantly, while the presence of the array of LSMs interacts in limiting the increase in the cogging force. A geometric optimization in regards to the relative positions of the LSMs along the curvilinear tracks is subsequently carried out in order to reduce the total cogging force.

1. Introduction

The Thirty Meter Telescope (TMT) project [1] aims to build one of the most technically advanced, ground-based optical telescopes with a 30 m diameter primary mirror capable to perform a broad range of groundbreaking astronomical research. In operation, the drive system of the telescope needs to perform slewing, pointing and tracking motions to high accuracy, with minimal execution time and jitter [1,2]. Stringent motion requirements are imposed on the two main telescope axes, the azimuth and the elevation axes (Fig. 1). The azimuth axis allows a full 360° rotation of the telescope on a circular track of about 17 m in radius. The rotation about the elevation axis, obtained with a pair of semi-circular journals with radius of about 10 m, is limited to 135°. Due to the size of the telescope and acceleration required, the torque requirements of its drive system are substantial [1].

Direct drive electric motor systems have become common in telescope drive system designs due to the advantages of high stiffness, no friction, low alignment and maintenance requirements over conventional electro-mechanical drive systems [3,4]. For the next generation of Extremely Large Telescopes (ELT), such as the TMT, it is recognized that permanent magnet linear synchronous motors (PMLSM) are strong candidates for telescope drive. Based on the torque requirements, the proposed drive system configuration has 64 forcers for the azimuth motion and 36 forcers for the elevation motion. Two arrays of 32 straight forcers, 180° apart, are fitted over a 360° stator approximated by a ring of straight permanent magnet stators for the azimuth axis. Due to limited space around the elevation journals, a total of four arrays of nine straight forcers and 135° sector of stators as approximated by the same straight magnets are fitted for the elevation axis, with two arrays on opposite side each of elevation journal [1,2].

In PMLSMs the motion is in sync with the magnetic field produced by a polyphase winding (the forcer) and an array of magnetic poles (the stator). The motor analyzed in this study is an off-the-shelf system from Parker-Trilogy that is proposed for the TMT: a flat, single sided, slotted, iron-cored linear motor, with the magnetic flux generated transversally with respect to the direction of motion [5–7]. The motion is generated and controlled using a sinusoidal current waveform synchronized with the pole pitch through commutation. The disadvantages of the PMLSMs are force/torque losses mainly due to heat and material hysteresis, and disturbances caused by electromagnetic phenomena [5,6], e.g., cogging force, back electromagnetic force (EMF) waveform, self and mutual inductances [8–10]. These disturbances compromise the motion accuracy by inducing speed ripples, structural vibrations and general control system difficulties, especially at low

* Corresponding author at: Mechatronic Systems Engineering, School of Engineering Science, Simon Fraser University, 250-13450 102nd Avenue, Surrey, BC, Canada V3T 0A3.

E-mail address: ed_park@sfu.ca (E.J. Park).

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