

The Mathematical model of 3-D planar based on Multimedia Flash and Simulink

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Abstract—this work reports on a high speed flexible automation system based on Cartesian multi-axis coordinate system linear step motor developed, in the target application as a multi-use robot system. The task of this work is to constructs an interactive multimedia page for study and researches the principle's work of drive of direct action linear step motor, Development the mathematical model and implementation of a closed loop control, based MATLAB/SIMULINK, Study the static and dynamic characteristics of the motor movement which is restricted to the trajectories accessible through the given commands.

Keywords—mathematical model, 3-D Plana, MATLAB and Simulink, Multimedia Flash.

III. Introduction

. Modeling and simulation play a number of roles in our studies. They provide us with a clearer understanding of our physical system, producing rich and valuable information about the way a real technical system actually works. Simulation also enables us to design experimental protocols, and even to make extrapolations of behavior in domains that cannot easily be tested in the laboratory. Today the laboratory of Mathematical Modeling of Technical Systems deals with mechatronic and micromechanics systems, control systems for precision equipment. We have large experience in computer modeling and simulation, creation of software and hardware for precision coordinate devices and control systems for linear stepping drives and servo-motors [2].

This work report aims to providing an interactive macromedia page as packaging for education. The user can controlling the high speed and precision coordinate system using a set of commands descried bellow for controlling the motion, manipulation and processing of system's feedback sensors are used. The visualization of the characteristic of movement of the system are carried out using MACROMEDIA FLASH MX6, The complete mathematical model of planar linear step motor are derived using MATLAB/SIMULINK.

IV. The Physical aspects

The planar linear step motor basically designs from two parts as in figure-1, the stationary part what so called platen and moving part as a forcer, Between their active surfaces an air-gap must be maintained, either by mechanical means (wheel), or by an air bearing which lifts the motor using pressurized air,



Figure 1. planar linear step motor

the motor working according to the principle of the electro-mechanical energy conversion [1]. A magnetic field, charged by electric energy induced by coils of electrical windings embedded in the forcer, will try to move the forcer so as to minimize the energy content of that field. The platen made from electrical steel to closes the magnetic path of the core and contains a set of teeth match the size of the forcer legs and the distance between each two teeth is called pitch p and motor displacement x as per figure (2).

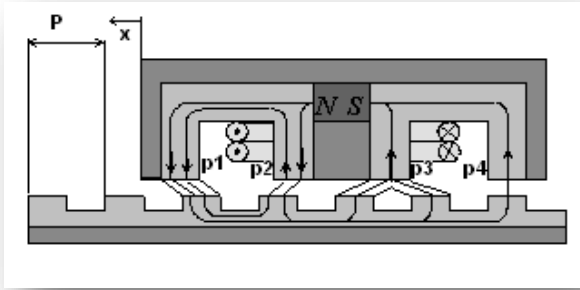


Figure 2. Cross-section of linear step motor

The air gap between the forcer and platen has a high reluctance to the magnetic flux Φ . The magnetic energy stored in the air-gap can be derived from the equation [1]:

$$(1) W_G = \frac{1}{2} \times R_g \times \Phi^2$$

Where

Φ = flux through the pole face and air-gap
 R_g = air-gap reluctance

Assuming the magnetic energy stored in the core and the plate is negligible compared to the air-gap energy, the mechanical force F which caused the displacement x along the axis is:

$$F_{total} = \frac{2\pi R_o K_g}{P} \Phi_{pm} \Phi_{cA} \sin\left(\frac{2\pi x}{p}\right) \quad (2)$$

$$F_{total} = \frac{2\pi R_o K_g}{P} \Phi_{pm} \hat{\Phi}_c \sin\left(\omega t - \frac{2\pi x}{p}\right) \quad (3)$$

Where

$\Phi_{cA} = \hat{\Phi}_c \sin \omega t$ flux caused by electrical coil as phase A.

The term $\omega t - \frac{2\pi x}{p}$ is called the lead angle between the electric field and mechanical position has the great importance for force generation.

V. Mathematical modeling

The formulation of the mathematical model to create a tool for understanding the dynamic behavior of the linear step motor, with the help of computer simulation software MATLAB and SIMULINK the mathematical model of a linear planar step motor is designed, based on a set of dependence equations, these equations have been derived from the electrical, magnetic circuit of the motor and from Newton's classical mechanics. From the electrical circuit we can derive the equation:

$$I_{m.A} = \frac{1}{R_{dw}} \left[u_A - n(\dot{\Phi}_2 + \dot{\Phi}_3) \right] \quad (4)$$

Where

$I_{m.A}$ = magnetizing current

R_{dw} = drive resistance + winding resistance

n = the number of forcer coil windings

$\dot{\Phi}_i$ = magnetic flux through pole face i

From the magnetic circuit domain of the motor (forcer and platen) we can derive the equation:

$$\dot{\Phi}_{23} = \frac{u_A}{n} + \frac{R_1 R_3 - R_2 R_4}{(R_1 + R_4)(R_2 + R_3) + (R_1 + R_2 + R_3 + R_4)(R_{pl.A} + R_{pm})} \times \frac{R_{dw} M_{pm}}{n^2} - \frac{(R_1 + R_2)(R_3 + R_4)(R_{12} + R_{34} + R_{pl.A} + R_{pm})}{(R_1 + R_4)(R_2 + R_3) + (R_1 + R_2 + R_3 + R_4)(R_{pl.A} + R_{pm})} \times \frac{R_{dw} \Phi_{23}}{n^2} \quad (5)$$

$$R = \frac{l}{\mu A} \quad (6)$$

Where

Φ_{23} is the magnetic flux through the pole face 2,3

R_i is the magnetic reluctance of the pole / air-gap path i

M_{pm} is the magneto-motive force of permanent magnet

μ is the permeability

l is the length of the flux path

A is the flux path cross section area

By applying Newton's law the force generated can be derived as:

$$F - F_d - m \ddot{x} = 0 \quad (7)$$

Where

m is the total forcer mass

F_d is the drag representing the core losses

Figure 3. describe the mathematical model of the step motor using MATLAB and SIMULINK and differential equation given above, with immediate relations between the system variables, and mechanical geometrics of the motor including nonlinearities.

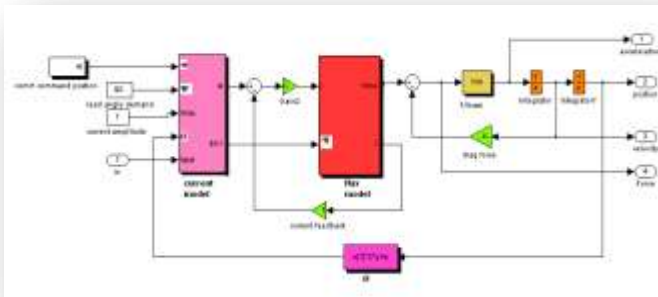


Figure 3. Mathematical model of linear step motor

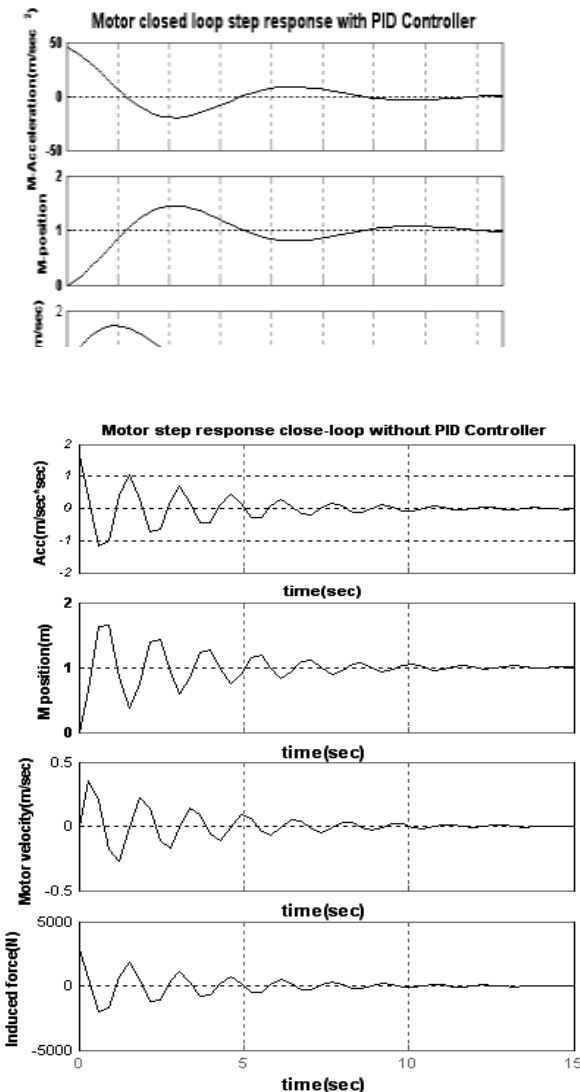


Figure 4.a Step response of closed loop system with PID controller

The open loop and closed loop system step response are studied, and we design the PID controller to improve the performance of the system, using the bode-plot method.

Figure 5.b Step response of closed loop system without PID controller

IV. Modeling basis of Multimedia Flash

As a mentioned above, the aim of this paper is to provide an interactive macromedia page as education package, the user can control the linear planar step motor, just by entering the proper motion commands discussed below, to the page in menu editor shown in figure 1., we designed this page using Macromedia flash in such way given as velocity and position commands to the mathematical model, which illustrates the dynamic behavior of the system to these commands, and user can also see the system characteristics graphically like position error, and induced flux which difficult to do it in the real system.

A. Command of movements and delay (PA, PR, AA, DL):

- Command PA X,Y,Z,C,B;

The command is meant for the definition of the interpolated moving in an absolute coordinate system.

- Command PR X,Y,Z,C,B;

The command is intended for the definition of the interpolated movement of the drives in the relative coordinate system.

- Command AA Xcentre,Ycentre,Angle,Z;

The command is intended for the definition of moving in a plane of two coordinates X-Y on an arc of a circle (circle interpolation).

- Command DL

The command intends for assignment of timing delays

Where:

X centre is the Absolute coordinate of centre of an arc on an axis X (μm).

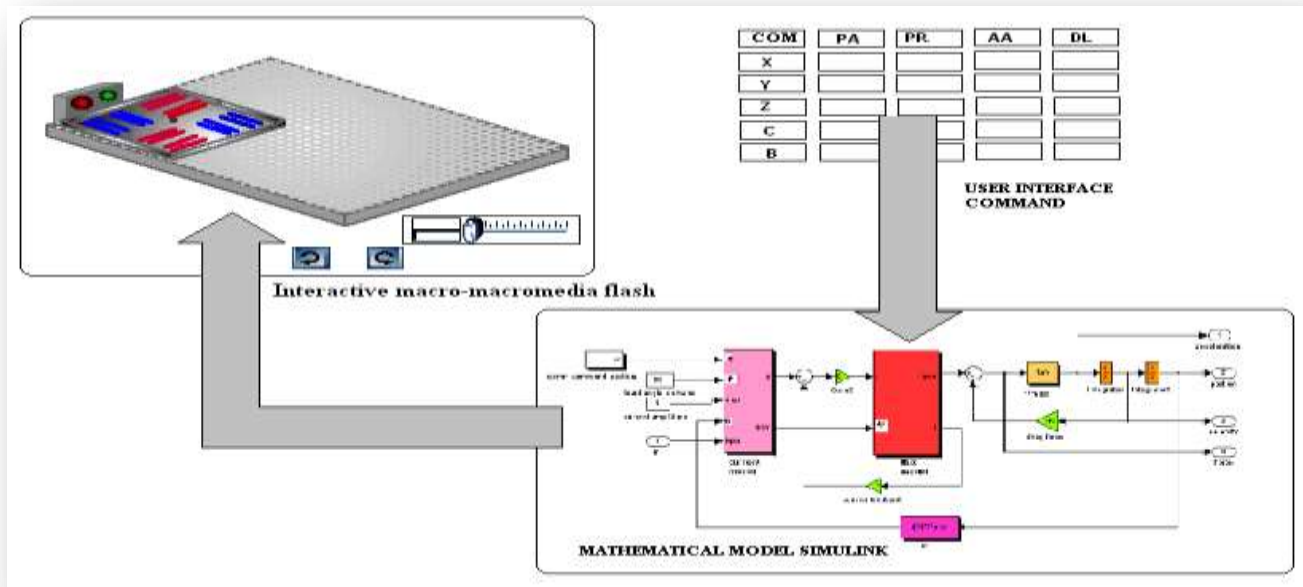
Y centre is the Absolute coordinate of centre of an arc on an axis Y (μm).

Angle is the corner of an arc in degrees (Angle > 0. - driving counter-clockwise).

Z is the relative moving on an axis Z, which is fulfilled proportionally to length of a corner.
 X is the final absolute position of a drive on coordinate X (μm).
 Y is the final absolute position of a drive on coordinate Y (μm).
 Z is the final absolute position of a drive on coordinate Z (μm).
 C is the final absolute position of a drive on coordinate C in 0.001degrees.
 B is the final absolute position of a drive on coordinate B (μm).
 Time is the delay in ms between the previous command

- After that, the model is run in SIMULINK and the output data are exported from MATLAB using extended Markup Language (XML)
- Finally, the results of modeling imported into Macromedia Flash are the basis for visualization of the movement process.

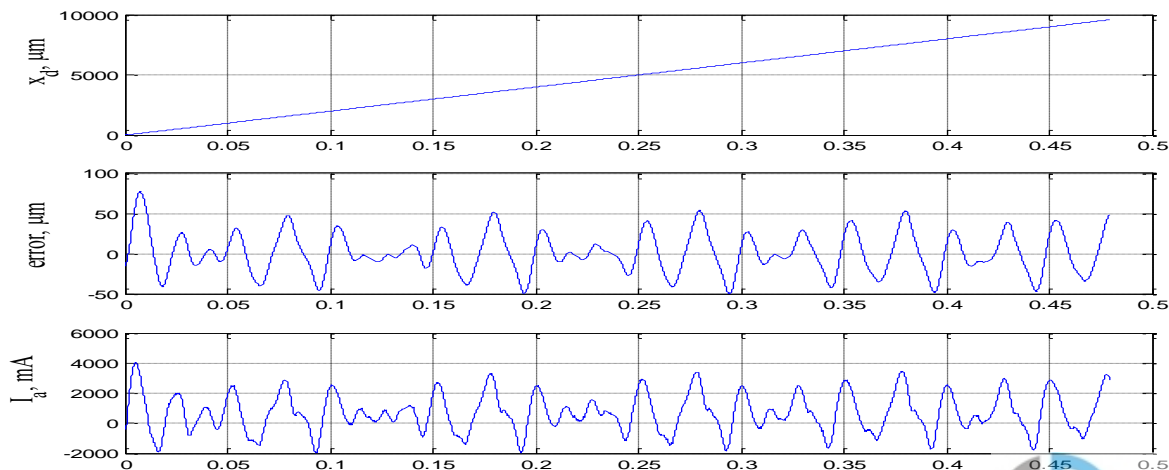
Figure 6. over all system simulation results



and execution next command

Figure 6. overall system simulation

The process of simulation consists of three steps:



As an example, of computer simulation, the Fig.5. Contains the results of a command set:

FA 10 15

KX 40 0.5 1000 5000 0.1

PA 10000

The results of system simulation is shown in figure 6. It describes the linear step motor displacements in micrometers and the current variations in phase A, and error value between the actual displacement and the current value.

V. Conclusion

The visualization of the motion characteristics of liner planar step motor are carried out using MACROMEDIA FLASH MX-6, where the set of commands for controlling the motion in three degree of freedom used. The position and velocity demands are initialized as nominal trajectory. The mathematical model has design using MATLAB/ SIMULINK based on the physical, mechanical and electrical laws and basic theory and the visualization interactive macromedia page can be applied as education tool for representation the principles and control the motion of high precision coordinate system.

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