Mathematical Model of a Linear Electric Actuator with Prosthesis Applications

Edrey D. Ruiz-Rojas[1], J.L. Vazquez-Gonzalez[1], Ruben Alejos-Palomares[1], Apolo Z. Escudero-Uribe[2], J. Rafael Mendoza-Vázquez[2]

[1] Research Center for Information Technologies and Automation (CENTIA) Universidad de las Américas Puebla, México.
[2] Instituto Nacional de Astrofísica, Optica y Electrónica, Puebla, México
E-mail: josel.vazquez@udlap.mx

***Abstract* — This paper presents the kinematic and dynamic model of a linear electric actuator. The kinematic model was obtained by geometric analysis. The dynamic model was obtained with Lagrange's methodology. This linear actuator forms part of parallel prosthetic elbow with 3 DOF developed in the Instituto Nacional de Astrofísica, Optica y Electrónica (INAOE). This linear actuator will be used in the elbow prosthesis in order to emulate the capacity of a muscle to extend and contract in a linear way. In this paper we show the behavior the electromechanical according to the equations of the system and its physical parameters. The model includes the analysis of electrical and mechanical parts. The model includes conversion of rotational movement to linear movement and relation torque-force necessary for emulating a human muscle.**

***Index Terms*— System modeling, Muscles, Motion analysis, Position control.**

I. Introduction

A linear electric actuator is an electromechanical system composed by: electric motor, planetary gearhead and ball-screw. This kind of system let us emulate an electromechanical muscle and to have enough force to emulate the behavior of a human muscle.

The ball-screw is a mechanical element having very low coefficients of friction [2]; therefore, it is used in this linear electric actuator. In addition, these elements are used to execute linear movements with great performance because they provide a transmission with relatively high rigidity and reduction coefficient that allows having enough force after conversion of rotational to linear movement. The motor is an electric component that transducers voltage in torque and angular displacement [4]. Controlling the level of voltage we can control the position and speed of the system.

In this article, we show the equations of the electromechanical system, its transference function and representation in space of states for an actuator of DC with a planetary gearhead and a load of ball-screw, which transform the angular displacement of the motor to linear movement. Graphics of behavior obtained in Matlab are presented to show the capacity of this linear electric actuator.

II. Modeling

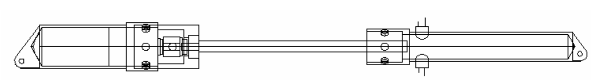

Fig. 1. Scheme of linear electric actuator mechanism.

A. Artificial muscle

Figure 1 shows a linear electric actuator diagram. The actuators have the capacity of emulate the move of a biological muscle. This device could be considering an artificial muscle with characteristics like muscles human for elbow prosthesis.

B. DC Motor with rotational load.

Figure 2 shows an electric diagram of an electric motor. There is a magnetic field by means of stationary permanent magnets called fixed field. In the armor a current $i_a(t)$ circulates trough this magnetic field to right angles and detects a force, $F = Bl^* i_a(t)$, where B is the intensity of magnetic field and l is the motor's inductance.

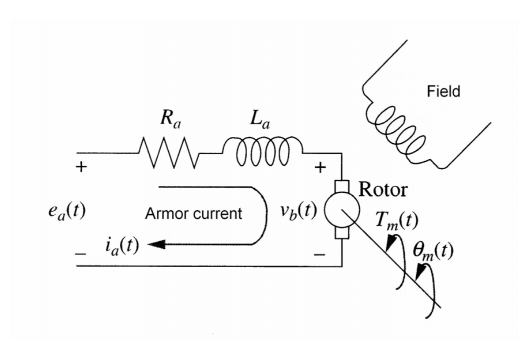

Fig. 2. Schematic diagram of the DC motor.

0-7695-3120-2/08 $25.00 © 2008 IEEE
DOI 10.1109/CONIELECOMP.2008.29