NEW CONFIGURATION OF LINEAR ELECTROMECHANIC ACTUATORS WITH APPLICATION TO INTELIGENT SYSTEMS OF FABRICATION

Vasile NĂSUI, Eugen PAY, Radu COTEȚIU, Mircea LOBONȚIU, Nicolae UNGUREANU

Abstract: The paper present the newest solutions of linear acting of electro mechanic linear actuator archived within a research grant CNCSIS. There are high lightened the configuration structures bother mechanical and control and order ones compatible with the modern requirements and the top performances of intelligent flexible systems of fabrication where they are frequently used. Starting from the virtual prototype we'll find a series of different constructive developments of some original solutions to different applications of linear movements. The paper is structured in the following movements: in the first part it is about modeling the actuators using virtual instrumentation followed by a second part –about the typical systems of control of the movement on the algorithmic basic and in the last section new developments of electromechanical linear actuators.

Key words: actuator, mechatronic, intelligent systems of production, machine-tools, motion control.

1. INTRODUCTION

The work refers to theoretical, experimental researches and dynamic modeling of electromechanical linear actuators equipped with mechanical drive, through ball screws and roller screws.

The electromechanically linear actuator was constructed to study the implementation of a digital control algorithm and to provide an experimental laboratory in which students can easily adjust constants and examine their effects on the device. The linear actuator is composed of a motor turning a screw in which the nut on screw is not allowed to rotate.

This allows linear motion of the nut for the length of the screw. A position at some point along the screw is commanded by the user and the motor turns the screw until the nut reaches that position [1, 5].

Among the practices and the techniques of modern design with a special impact applied to the electro mechanic linear actuator is: the digital prototype, the virtual place and the virtual make. These have as a working basis the concept of competing engineering accepted by everybody as an industry practice.

The project deals with the assimilation of some modern systems of action of linear electro mechanic actuator type used to machine-tools from intelligent systems of production and to the ecologic industrial tools on the basis of some invention patent which should replace the classical ones, immediate use as acting mechanisms of the tubs and obstacle on the hydro technical arrangements [8, 9].

This research offers a new concept concerning the development of new systems of linear actuation and simulation using adding numerical programs and virtual instrumentation.

2. TYPICAL PROGRAMMABLE MOTION CONTROL SYSTEMS

An actuator's function is to provide thrust and positioning in machines used for production or testing. One type is the electromechanical actuator, which converts the torque of an electric rotary motor into linear mechanical thrust (Fig. 1). The motion control system's purpose is to control any one, or combination, of the following parameters: position, velocity, acceleration, torque.

Many motion control systems are integrated into a larger system. Various computer-based devices, such as programmable controllers, stand-alone industrial computers, or mainframe computers serve to link and coordinate the motion control function with other functions.

Thus, a more integrated motion control system would appear as shown below: the assembly of the process of developing new products, covering the conception aspects, manufacture and the link between them.

The essential component of many automatic control systems is actuator (Fig. 2). The application of a specific command causes a corresponding signal at the input through action input transducer. The result is an unbounded increase in controlled variable and loss of control by the command source. The general form of the block diagram of a feedback control system is shown in the Figs. 3 and 4.
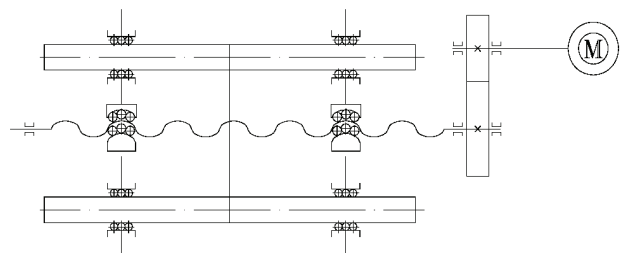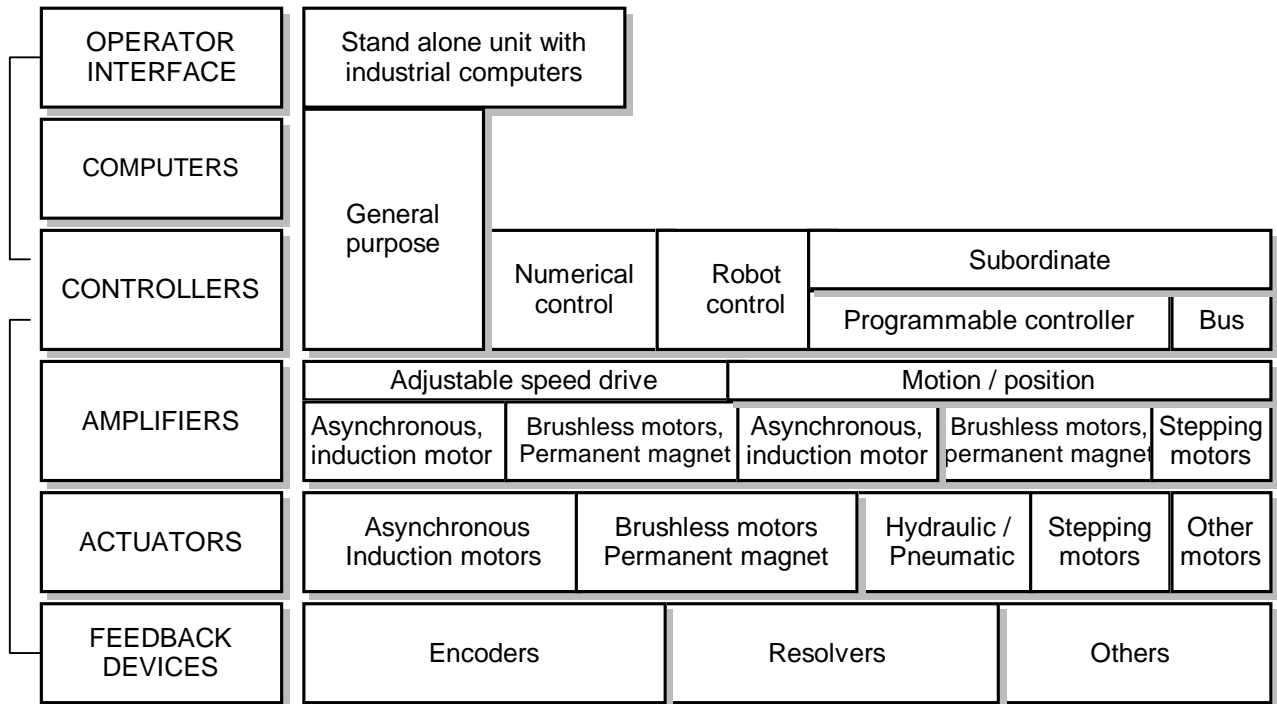

Fig. 1. Linear electro-mechanic actuator.

Fig. 2. Typical programmable motion control systems with actuators.
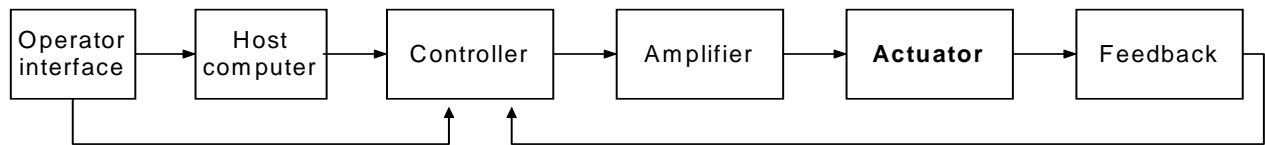

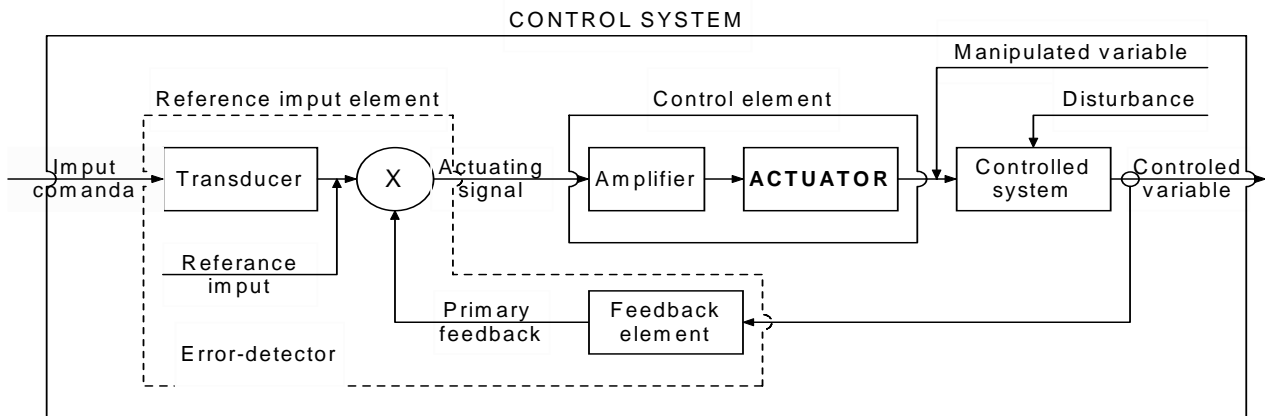**Fig. 3**. The purpose of motion control actuator.

Fig. 4. The block diagram of a feedback control system with actuators.

3. THE CONTINUOUS CONTROL ALGORITHM

An actuator's function is to provide thrust and positioning in machines used for production or testing. One type is the electromechanical actuator, which converts the torque of an electric rotary motor into linear mechanical thrust. To size such a linear actuator, the amount of thrust required by the load must be calculated.

For the study of the mechanical systems dynamics we introduce a mechanical – electrical analogy based on the fact that d'Alembert's movement laws for weight correspond with Kirchoff's laws for a certain equivalent electrical circuit.

The electrical circuits analogous to mechanical systems can be passive or active. The passive are made up of assemblies of resistances, inductances and capacitances whose dynamic response is analogous to the mechanical system and the active ones are made up of amplifiers of direct current arranged to carry out calculations the movement equation for a mechanical system exposed to a forced disturbance is of the following form according to d'Alembert's principle:

$$m \cdot \ddot{X} + c \cdot \dot{X} + k \cdot X = F(t). \tag{1}$$

According to Kirchoff's law, the fundamental equation of an electrical circuit made up of resistance R, inductance L and capacitance C, connected in series, is:

$$L\ddot{Q} + R\dot{Q} + \frac{1}{C}Q = U(t). \qquad (2)$$

A block diagram of the system (Fig. 1) is shown in Fig. 5.

We observe that the equations are the same; therefore, we can establish correspondence among the analogous parameters which allow solving electrical circuit's dynamics problems by the theoretical and experimental methods.

According to relation 1, the idealized equation for continuous control algorithm is,

$$F(t) = K_p \cdot X(t) + K_i \int_0^t X(t) \cdot \mathrm{d}t + K_d \cdot \frac{\mathrm{d}}{\mathrm{d}t} X[f(t)], \quad (3)$$

where: $F(t)$ is the output of the controller at time t; K_p – the proportional gain constant; K_i – the integral gain constant; K_d – the derivate gain constant; $X(t)$- the error at time t.

For small sample times this equation can be turned into a difference equation by discretization.

The derivate term is replaced by a first-order difference equation and the integral term is approximated using trapezoidal integration. This equation required storage of past errors.

The intermediate equation can be transformed into a recursive equation where only the previous output, current error, and last two errors must be stored.

The final equation then takes the form

$$F(t) = F(t-1) + K_1 E(t) + K_2 E(t-1) + K_3 E(t-2), \quad (4)$$

where: $F(t-1)$ is the previous control output; $E(t-1)$ – the previous error; $E(t-2)$ – the error proceeding $E(t-1)$.

The LabVIEW program allows the selection of real numbers for gain constants. These constants, along with the sample frequency, are converted into K_1, K_2, and $K3$ according to the formula shown above.

The magnitude of the largest of these three numbers is selected then multiplied by 2 until the largest possible 15-bit value is reached. The number of times the constant is multiplied by 2 is the scale constant. The constant is used to scale the original K_p, K_i, and K_d constant. Then the K_1, K_2, and K_3 constants are once again formatted. The codes program transforms the constants K_p, K_i, and K_d into K_1, K_2, and K_3 for use with the discrete algorithm.
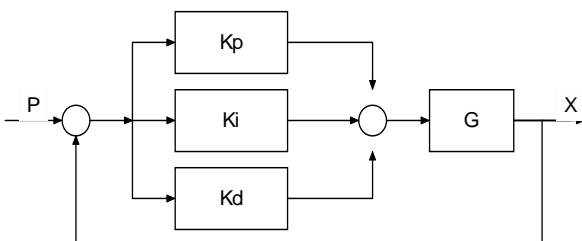
These numbers are rounded off and sent to the controller board with the scale and frequency values. It is important to note that the size of one constant or the frequency can affect the scale and therefore affect the resolution of another constant. The LabVIEW program communicates through serial port with the Controller, which can be enabled and disabled with program.

Also the modular control laboratory with this transmissions was used for my experimental research. The experimental test stand is presented in Fig. 6. The motion and the torque M_M are transmitted from the electric motor M towards the linear motion systems with ball screws.

For the calculus of the acceleration moment, the algorithm of calculus differ, having more values and at different moments of the circuit while calculating the angular acceleration, the reduced insertion moment of the engine shaft, the inert ion moment of the screw, the angular speed, the linear speed, the pace of the screw, the inert ion moment of the engine and the necessary turation

Previous actuator research in the Laboratory BCE – UNBM focused in the electro-mechanical domain. Dynamic analysis of the prototype actuator correlates well with the linear mathematical model.

His prototype actuator is pictured in Fig. 7 [8, 9]. The prototype actuator is compared to a mathematical model and simulation which is formulated in non-dimensional terms for generality. Below is the block diagram (Fig. 8) of the control system in the continuous control form.

4. SUMMARY AND CONCLUSIONS

The research is of great importance it presents the calculation algorithms regarding the main dynamic parameters, power and mechanical efficiency.

The solutions presented from the cinematic point of view correlated to the one of controlling the movement is
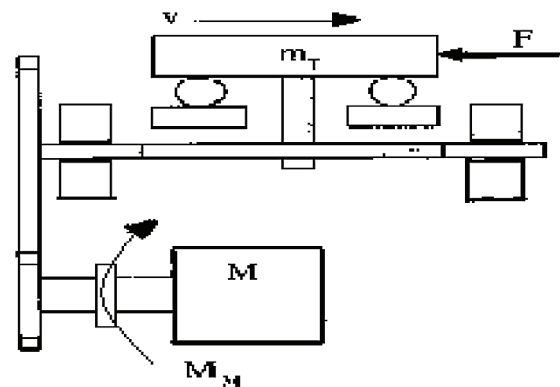
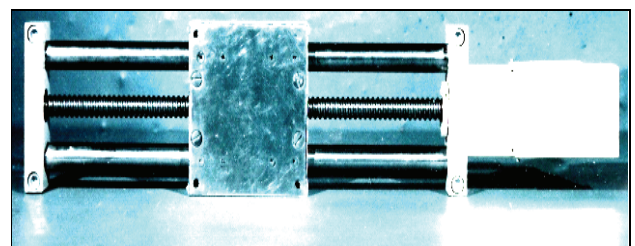**Fig. 6.** The experimental test stand.

Fig. 7. Prototype linear electro-mechanic actuator.

Fig. 5. The continuous control block diagram.

an important contribution to the development of some modern systems of linear acting for a larger range of applications, from the most common ones to the intelligent systems of flexible fabrication.

Their development is not limited to the top industry use which require high element regarding the generation and the control of linear movement. Pursuing a systematical tackling of the optimization by completing the dynamic model and with these parameters performant roto-translation systems has been achieved.

The work integrates itself into the present day researches in the field of developing modern mechanic transmit ions making contributions in their optimal design.

This research offers a new concept concerning the development of new systems of linear actuation and simulation using numerical programs and virtual instrumentation. In the future the researches can continue for the development of new applications on other types of mechanical transmission using this method and different modular control laboratory.

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