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Actuation of a Linear Electromechanical Actuator

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Abstract: *The present work aims to analyze an electromechanical actuation, composed of a system in which we have a linear electromechanical actuator, nut screw type, with balls, driven by an asynchronous electric motor with the rotor in short circuit and controlled by a frequency and voltage converter. This work is part of a large study that aims to try to optimize some operating parameters of a linear electromechanical actuator. First, some characteristics of electromechanical with ball nut type actuators will be mentioned, then a presentation of a frequency and voltage converter. Finally, some results of some measurements regarding the actuation of the linear electromechanical actuator with an asynchronous motor with the short-circuited rotor will be presented and concluded.*

Keywords: *Actuator, actuation, asynchronous motor, electromechanical, frequency converter, linear.*

1 INTRODUCTION

The electromechanical actuator is an assembly that converts the input quantity, be it electrical, pneumatic, thermal or chemical, into mechanical energy producing movement in rotational or translational systems. Actuators have a triple role, because they can take over and transmit loads, so they have a structural role, they also play a sensorial role, because sensors and transducers can be integrated into their structure, and the third role is actuation.[1]

As actuators or execution elements of a system, the actuator is the best way of movement in terms of handling, lifting, adjustment and precision in positioning systems for some machines, and the fields in which they are used are spread from to the medical and to the aeronautical or space field.[2]

The optimization of actuators has become one of the main concerns of industry and engineering, trying to develop them from a technical, economic point of view, implementation, miniaturization and offering real solutions for industry. They depend on the adaptation of the actuator to the multitude of systems for which they are used, offering a high energy efficiency, an appropriate technical solution, a low acquisition cost, a high speed for increasing productions and a reliability as long as possible.[5]

To successfully optimize an actuator system, a two-component synthesis is required. The first would be the structural synthesis, through which essential component elements are chosen for analysis and optimization so that they operate with the maximum possible efficiencies, and a synthesis of the entire control system, through which all sources of incoming energy are regulated, as well as loads at which the mechanism is subject to and these also at maximum values of the possible returns.[1]

1.1 Study of maximal randament
1.2

The friction loss reduction criterion is quantified after calculating the operation at a thermal regime appropriate to the working conditions, as well as the corresponding energy dissipation reported as a percentage of the nominal power. Efficiency plays a very important role, because, for example, reducers, in order to avoid the self-braking that occurs at certain transmission ratios. Here the randament criteria weight is equal to the cinematic weight, and the solution offered is actually a compromise between the two. As optimization solutions can be offered to replace sliding friction with rolling friction and achieve a scale optimum, and as a result of this solution, it can be seen in the randament variation diagram in figure 1.

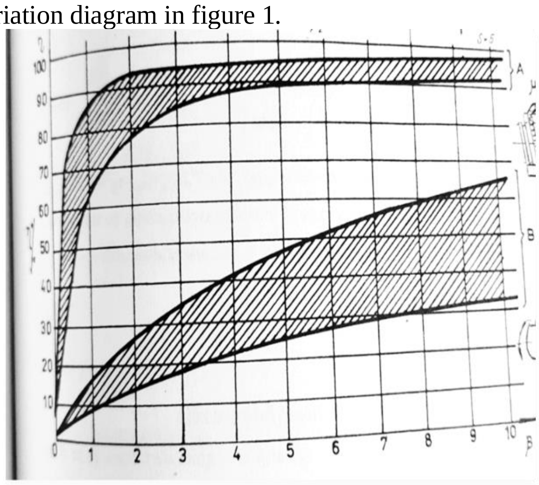

Fig.1 Randament variation chart[4]
A. rolling friction B. sliding friction

The determination of the maximum values of the mechanical efficiency of a screw-nut mechanism as well as the optimal slope of the screw with mean radius rm and with β being the angle of inclination of the thread, with φ taken as the friction angle between the screw and the nut starts from the theoretical relationship of efficiency. It is observed that for φ= constant, as a continuous and positive function, we have the maximum randament.

Knowing the geometry of the screw, the angle β and the friction angle φ, the efficiency of the helical torque can be determined. Since the friction angle depends on several factors, such as the quality of the contact surfaces, it is normally determined experimentally. For the experimental determination of the friction angle φ, the installation in figure 2 can be used, which is composed of the screw (1), the nut (2), the wire (11) wrapped over the pulleys (7,8) which have very little friction, almost negligible, the cross member (3) and the disc (4) together having the weight G. [3]

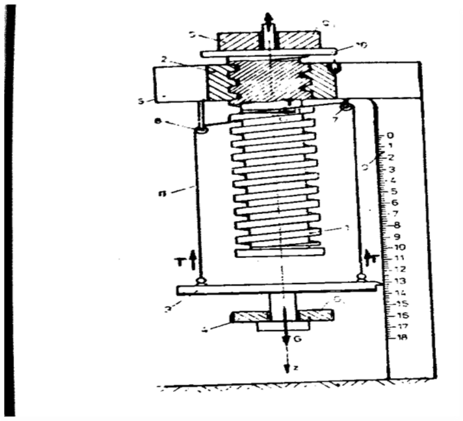

Fig.2 *Experimental installation for determining the friction angle [3]*

The crossbar has an indicator that registers the space traveled on the crossbar against the graduated ruler (9). On the platform (10) which forms a common body with the screw, the weights (5) are placed, which together with the screw's own weight form the weight Q. Under the action of the weight Q, the screw is set in motion.

2. ACTUATION WITH FREQUENCY CONVERTER OF AN ELECTROMECHANICAL ACTUATOR

Actuators, as mechatronic products, are the newest classes in the modern categories of execution elements that transform electrical energy into mechanical energy, producing linear motion by converting the rotary motion of the electric motor with the help of suitable, high-performance mechanisms that have high efficiency and which is constantly growing.

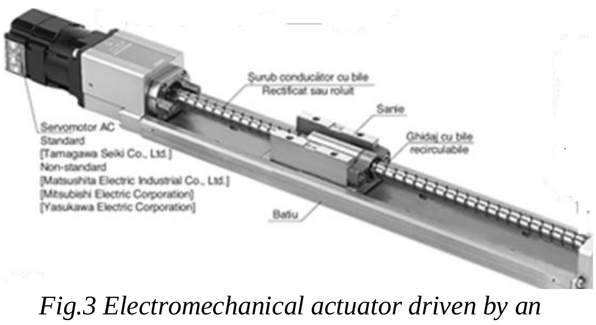

Fig.3 Electromechanical actuator driven by an electric motor[6]

The actuator, figure 3, includes two basic components, one that provides the necessary energy, based on the signals received from the numerical control system, the second that transforms the received energy into mechanical energy, used to develop forces/moments and/ or performing movements. In the case of using electrical energy, the first component can be implemented, on a case-by-case basis, with a simple relay or a block of power transistors, with appropriate logic and feedback circuits, as, in the case of using hydraulic or pneumatic energy, its distribution can be done with simple valves or servo valves.

Linear actuators convert energy into straight linear motions, as opposed to the circular motion of a conventional electric motor. They are based on displacement and linear motion, being derived from an energy source that is easily accessible.

These linear actuator modules are part of flexible intelligent processing systems, being components of machine tools with parallel kinematics, of their transfer and positioning systems, or of various types of industrial robots, and through the used test and measurement stands, multi-user research bases can be established, both for university researchers and for manufacturers or users of industrial mechanical equipment in the area. [5]

2.1 The frequency converter

Frequency converters with autonomous inverters are indirect electronic converters, which transform alternating current energy of constant voltage and frequency at the input into alternating current energy of variable voltage and frequency at the output, passing this energy through an intermediate state of direct current . In other words, these converters perform a double conversion of the consumed alternating current energy: first it is rectified with the help of a controlled or non-controlled rectifier, then it is inverted with the help of an autonomous current or voltage inverter.

Frequency converters, figure 4, present a series of advantages: variable and programmable speed, controllable acceleration and deceleration, changing the direction of rotation, protecting the semi-controlled motor, the possibility of powering a three-phase motor from the single-phase network, the possibility of remote action monitoring, easy interconnection with other systems, frequency, torque programming, braking, the possibility of locking the shaft in a certain position.

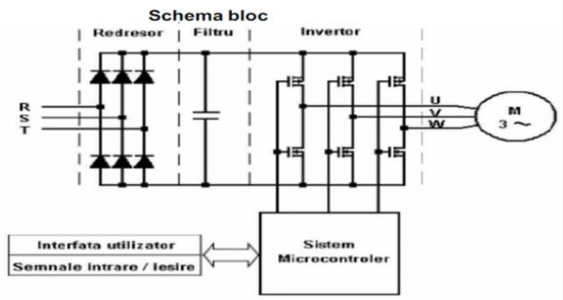

Fig.4 Block diagram of a frequency converter

Frequency converters can operate in open loop or closed loop. Open loop means they have no information about the actual speed of the driven motor. In this case, a mathematical modeling of the motor is used, in the memory of the microprocessor, so that depending on the current absorbed by it, an estimate of its speed can be made. This method works well above frequencies of 10 Hz. For good operation in the entire speed range, encoders mounted on the motor are used, which send the rotor position to the microprocessor in real time.

Fig.5 Frequency converter

Using the frequency converter, figure 5, can drive and process many applications and in many programmable ways. They can also control several motors at once, connected in parallel. If several motors are used in parallel, there are two possible scenarios, so the motors have equal power, and in this case the torque characteristics will remain optimized after the driver has been configured, and the second case is when the motors have different powers, in this case the torque characteristics will not be optimized for all engines.

3. SIMULATION AND MEASUREMENTS

The measurements were performed on the laboratory stand, figure 6, which can monitor the operation of the asynchronous machine with the short-circuited rotor.

Fig.6 Stand de laborator pentru studiul masinii asincrone

It was connected in an assembly, the linear electromechanical actuator with a ball nut screw type mechanism, a three-phase asynchronous motor with the short-circuited rotor that has the role of driving the actuator, and the electric motor was fed from a frequency converter or variator and tension.

The converter is fed from the electrical network, following which it will make two conversions of electrical energy, namely in the first phase the alternating current is transformed into direct current, and then for the output part, the waves are transformed and then filtered, from direct current to three-phase alternative form, for powering the electric motor.

The requirements for driving the electric motor are introduced, namely the converter is required to simply start the electric motor, providing increasing frequencies, starting from 5 Hz, up to the nominal frequency of the grid, namely 50 Hz.

Measurements are made for each frequency applied to power the electric motor, namely, with the help of an ammeter we measure the variation of the electric current on each phase of the motor, with the help of a voltmeter we measure the voltage distributed at its terminals, and with the help of the applications on the measuring stand we can analyze variation of drive motor speed.

Several measurements are taken one after the other with respect to the smooth start, figure 7, constant of the electric motor, after which measurements will be made with respect to the variable actuation part, figure 8, of an electric actuator system.

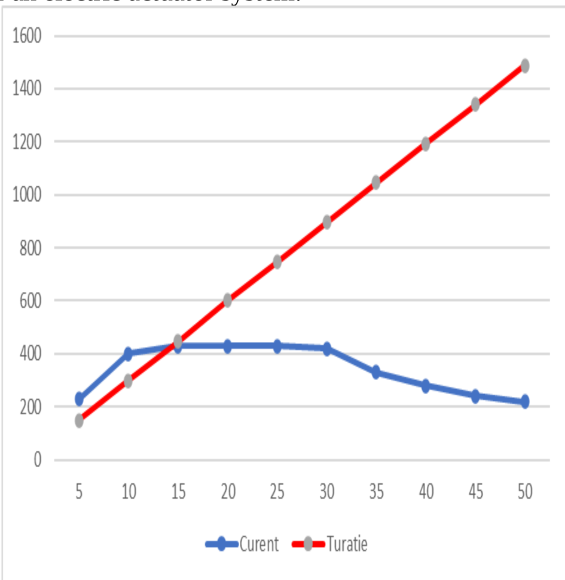

Fig.7 Constant regime

It can be seen from the two graphs presented that, for the constant drive, both the current and the revolutions of the machine have linear forms in the drive, on the other hand, when a variable mode of operation is executed, so we have several starts and stops, speed reductions , which can be similar in a process that uses linear electromechanical actuators in the mobility of some systems, current variations are proportional to the number of rotations of the asynchronous machine, have relatively higher values than what the nominal value means, which can stress the asynchronous machine, but they are controllable values with the help of some protections and they are also values that can be monitored very well, with the help of specific measuring devices, integrated in the base of the stands.

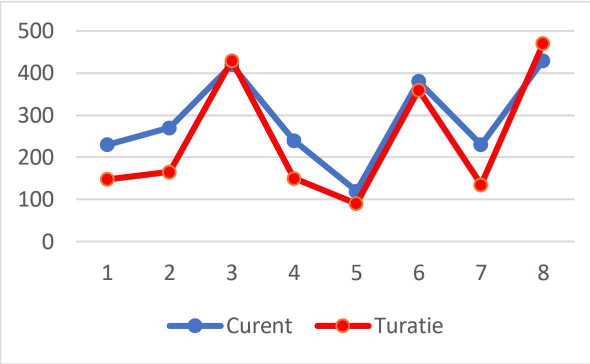

Fig.8 Variable regim

Application programs are examples of high-level grouping of lower-level component functions to execute typical programming in instrument operation.

4. CONCLUSIONS

In addition to the physical protection and actuation elements, virtual methods will also be used for the comprehensive control of all actuator system tests.
With the help of the software part, you can try to create an optimal method of entering data in the operation of the actuators, trying to enter some values.

Another study that can be done is that of the elements and actuation mechanisms of the actuators. Electric drive motors, construction types and their adaptability for the whole assembly, a thorough study in terms of energy efficiency optimization. All protection and control elements of drive motors, relays for thermal and overload protection, relays for protection against high currents, short-circuit currents, intelligent relays for controlling the operation of electric motors, with time supply will also be considered useful of all network and circuit parameters of the actuator system.

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