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ABOUT MODELLING THE FUZZY CONTROL WITH REACTION POSITION FORCE WITH THE ELECTROMECHANICAL ACTUATORS

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Abstract: *This article refers to about modeling the fuzzy control with reaction position force with the electromechanical actuators. This paper shows that similar fuzzy functional regulations can be used instead of the classical ones, which can be adjusted more conveniently and where the modification of the parameters has a special importance. By means of fuzzy movement control equipments, the control is simplified as far as programming is concerned, task that does not require a special operator qualification. The modeling of complex system through fuzzy theory represents a method much simpler than the classic method. This brief paper outlines some background of standard proportional integral derivative control and how the implementation of fuzzy logic can improve your single feedback control systems. From the structural point of view, the paper contains two parts, one regarding the fuzzying process and the mathematical expression of the experimental data, and a part two dealing with the definition of the actuator as a fuzzy system.*

Key words: *linear electromechanic actuator, virtual simulation, fuzzy logistic, controller, mechatronic.*

1. INTRODUCTION

The actuators having multiple applications both industrial and household become more useful in the use of fuzzy logistic and of these products. Owing to continuous developing equipments based on new solutions, the electro-mechanic acting achieves more and more precision. In view of constructive and functional optimization of the actuators and of the extension of their application domains new methods and techniques are being tried in present researches.

Thus the fuzzy logistics represent a new conception applied in the field of regulating different processes. It is known that the regulating and optimization systems have at their basis the mathematical pre-working of some numerical data by means of some transfer functions such as regulators obtaining precise output data.

It is not always that the function of the used actuators in different domains can be described and that is the reason why approximately “vague” expressions are used.

The mathematical theory of vague or “fuzzy” [7], sets initially applied in the theory of automats has rapidly developed in diverse applications starting from programming household appliances to the optimization of complex processes.

The applied researches in the field of the actuators have aimed at creating an assembly or configuration called stand in order to study the dynamic behavior using a numerical data acquiring module and a module of optimization of fuzzy logistic parameters [2, 10].

The approach of the two categories the one of the theory of mathematic statistics and that of the theory of the fuzzy systems show some mutual connections between the principles of the two branches of the science.

The development and the appearance of the statistic methods in the industrial production on one hand, the beginning and the expansion of the approximate reasoning on the other hand, allowed the revelation of some surprising interferences between the two subjects destined to the development and the understanding of statistics technical thinking, the fuzzy one and modeled one.

Replacing the classical models with the fuzzy models of the electromechanical actuators, which require rigid calculations, is constant preoccupations in this field. These used a systemic approach of designing methodologies of fuzzy inference systems which eliminates the incertitude’s in choosing the appurtenance functions and the set of rules.

The fuzzy system has destinations in generating the trajectories of the type of actuators and the way of control movement.

The paper continues the author’s preoccupation regarding the research of the electro-mechanic actuator mechanisms and refers the results obtained by applying a multiple parameters measuring stand on these types of actuators.

The research and the data regarding this type of mechatronic products relatively new, based on analysis and structural and kinematic synthesis led to several applications and different denominations.

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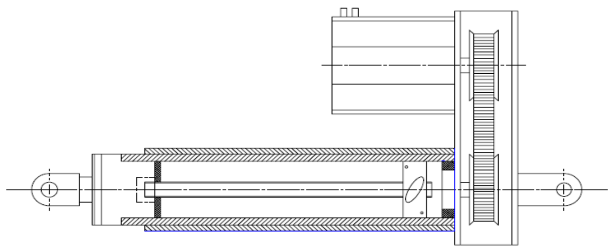

Fig. 1. The linear electromechanical actuator.

We are going to focus on this starting from the classic al measuring structure to the general method of solving the measuring problem of the kinematic and dynamic parameters in the case of the structural configuration of the type of linear actuator mechanism type.

The study of technical considerations proves that the performances of electro-mechanic actuator have evolved towards complex computerized automation towards mechatronic products.

In this context the presented variants are an evolved stage to solve the complex automatic problems; the evolution towards superior stages will be done by appropriate sensor equipment and by appropriate software. In order to determine the measures that characterized the whole functioning of the actuators the stand is equipped with parametric traductors and measuring and recording devices including the numerical data acquisition system.

Some flaws can be emphasized, because some inference fuzzy systems, which can be implemented only on the basis of formal knowledge, do not ensure the warranty of a stable and sure functioning in contingencies conditions.

The inference systems for the experimental research can be used to automatically generate the appurtenance functions and identification of the system.

There are plenty of papers about the fuzzy system; the fuzzy logic [2, 7, and 10] and the statistic modeling of experimental data, but a parallel between the two theories is less approached.

The linear actuator (Fig. 1) is composed of a motor turning a screw in which the nut on screw is not allowed to rotate. One type is the electromechanical actuator, which converts the torque of an electric rotary motor into linear mechanical thrust.

Linear actuators are used in a variety of applications across numerous industries, including commercial kitchen equipment, agriculture machinery, high-voltage switch gears, train and bus doors, and medical machinery. There are many others, such as those in the field of human mobility and ergonomics (where safety, compactness, low noise, and comfort are the goals).

Typical end uses in these latter areas include medical beds, patient lifters, wheelchairs, and adjustable tables and workstations.

Electromechanical linear actuators are designed to provide precision, efficiency, accuracy, and repeatability in effecting and controlling movement. These devices often serve as practical, efficient, and relatively maintenance-free alternatives to their hydraulic or pneumatic actuator counterparts.

The electromechanical acting can be developed by using appropriate control destinations such as the loading equipment the actuators have to fulfill strict and stable criteria in any situation.

The functioning conditions of the machines impose on the used actuator some conditions which do not depend on the type of the screw. The analysis and the optimization of the construction is achieved by stand and machine tests.

Monitoring the actuators can be achieved by means of different engines of different sizes; electro mechanic acting's with classical asynchrony engines with dynamic regulation by means of frequent converter.

To achieve intelligent actuators, the first step is to use a new type of movement control such as the fuzzy one which offers important advantages.

2. MODELING THE FUZZY CONTROL WITH REACTION POSITION FORCE

Mathematically, fitting a curve of lower order would produce a fairly inaccurate representation. Therefore, a higher order curve fit would be appropriate to accommodate the noisy signal. A few products which have benefited from the implementation of fuzzy logic are: making intelligent decisions and minimizing travel and power consumption; anti lock braking systems with quick reacting independent wheel decisions based on current and acquired knowledge; actuator with automatic move control based on signal and environmental conditions; and finally, most importantly to this article, single loop temperature and process controls.

In addition, if the system tends to have changing thermal properties or some thermal irregularities, fuzzy logic control should offer a better alternative to the constant adjustment parameters.

In the absence of knowledge of the underlying process, a Proportional Integral Derivative (PID) controller is the best controller. This type of controller uses feedback from the process it is controlling and takes action based on the error.

By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation.

The development of the microprocessor based PID control has replaced a majority of the thermostat type devices. Most controllers that are microprocessor based have an auto tune function which operates a system experiment as shown in Fig. 2.

This experiment helps to determine the thermal characteristics of a particular system.

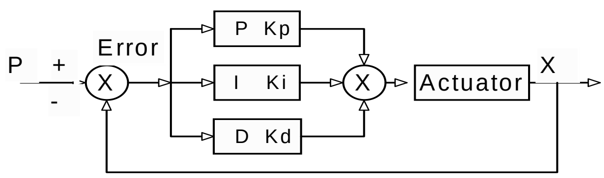

Fig. 2. Established actuator block scheme.

The application of adaptive fuzzy control on the actuators allows the maintenance of a constant working force when the working conditions undergo changes of the environmental conditions.

Experiments have provided that adaptative fuzzy controller have better performances than the conventional ones that are limited to variations. It is know that a controller has to eliminate any significative input error of the process by a control adjustment, to prevent the over passing an $Y_{\max\min}$ value and to ensure a stable functioning.

The fuzzy controller have block diagram in figure: basis for knowledge, basis for rules, scale factors, fuzzying, inference, defuzzying, process, input, output, traductors, fuzzy control system, in closed loop comprises precise quantity.

At fuzzy controller of type PCI, can be represented thesis [2]:

$$K_u \cdot \Delta y(k) = f\left[K_e \cdot e(k), K_d \cdot \Delta e(k)\right], \quad (1)$$

where:

y is the control;

e – the error at time t;

k – the sample time;

K_u, K_e and K_d – scale factors for *e*, Δe and Δu;

f – is a non-linear function, the output of the controller at time *t*.

Thus the error of the system is represented by operators of type min. and max., of the following form,

$$\tilde{\varepsilon} = \tilde{y} - \tilde{y} = \max\left[\min\left(\varepsilon_y(u), \varepsilon_{y'}(v)\right)\right], \quad (2)$$

where the operator of max type acts after all the values *u* and *v* which satisfies $u + v = 1$ corresponding to some linguistic (small, medium. big etc,) for values between 1 and 1.

Also the equation of the model of the fuzzy type is of the form of a linear system

$$\tilde{y}_e = \sum_{k=0}^{N} \tilde{a}_k \tilde{x}_{n-k} \quad (3)$$

where $\tilde{y}_e$, $\tilde{a}_k$, $\tilde{x}_{n-k}$ are fuzzy numbers.

The coefficients $\tilde{a}_k$, as fuzzy number correspond to a description of qualitative type of the system.

To achieve intelligent actuators, the first step is to use a new type of movement control such as the fuzzy one which offers important advantages.

Tuning a proportional integral derivative (PID) controller involves adjusting K_u, K_e, and K_d to achieve the "optimal" system response. 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 general form of the block diagram of a feedback control system is shown in the Fig. 2.

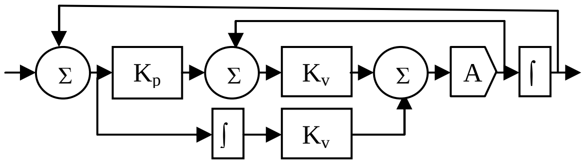

Fig. 3. The closed loop position control systems.

In order to develop and optimization pattern according to very strict engineering requirement it is necessary the introduction of a number of performance criterion and the formulation of some appropriate objective functions. The actuator controller should be reliable itself and independent from other equipment failures.

The electromechanical unit is controlled throughout a power output block. The controller only sets power control and direction lines to a required state and the power output realizes powering of motor.

The controller gets information about the load of the unit throughout load line. A typical the closed loop position control system is sketched in Fig. 3.

3. THE CONTROL OF THE POSITIONING OF THE TRAINED LOADING

The control of the positioning of the trained loading and the modeling of these positioning systems require an equation or systems of non-linear equation which imply some parameters difficult to identify, such as the frequencies of precision of the composing equipments, the friction forces etc.

The most comfortable and efficient solution could be the use of the fuzzy regulation in the structure of these systems. To achieve a system based on fuzzy logics it is necessary to choose a certain number of linguistics variants to which sets of qualitative values and belonging functions are associated.

To the input values, degree of belonging to the appropriate linguistic variants are associated, operation that is called fuzzification signals.

Unlike the systems of classical regulation where the standard regulator gets at the input the value of the resulted error as difference between the control value and the reaction value, in the case of the system of fuzzy regulation it is necessary to determine the value to be regulated and some other values that characterize the dynamic behavior of the system since these constitute input values for the fuzzy regulation.

The structure of the fuzzy regulation system is presented in Fig. 4.

With a control architecture, some of the information available to the algorithms is: the error signal, the process variable and the set point variable; change in error from previous cycles to the current cycle; changes to the set

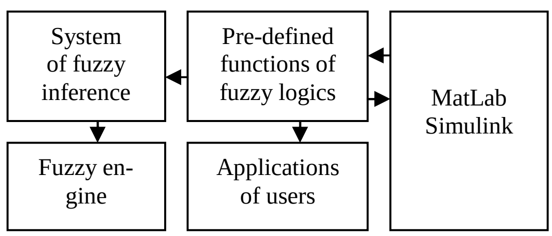

Fig. 4. Linking pattern between fuzzy modules and simulating MatLab.

point variable; change of the manipulated variable from cycle to cycle; as well as the change in the process from past to present.

Also available, in addition to the above, are the multiple combinations of the system response data. As long as the irregularity lies in that dimension which fuzzy decisions are being based or associated, the result should be enhanced performance. This enhanced performance should be demonstrated in both the transient and steady state response**.**

In the basis configuration in order to acquire the signals associated to the functional parameters of the testing process, momentary sensors-speed, incrementing positioning sensors and sensors of accelerometer type are used. Additionally, according to the testing applications other force sensors, vibrations, temperature sensors can be introduced owing o the open modular structure. These sensors are connected a special acquisition equipment connected to the central calculator-sensor interface.

For dynamic handling and automation processes, intelligent actuator offers position and control actuator whereby the mechanical actuation unit is combined with an intelligent positioning motor. The intelligent actuator has been designed for operation with frequency converter, a position sensor and position control.

The intelligent actuator includes the following components: thrust unit with designed screw with maintenance free, positioning motor asynchronous with thermal contact and frequency converter, pulse encoder with position electronic.

The parameter setting for ramp function, speed or acceleration control and slow down is realized by analog input channels continuous position and speed, digital control output channels via opto-coupler, programmable. Each of these positions can be approached at a given speed or a speed that is variable, acceleration and deceleration ramps are separately defined.

The inference systems for the experimental research can be used to automatically generate the appurtenance functions and identification of the system.

The Mat Lab programming environment has predefined functions in order to external modules and as the inference system and the fuzzy engine (Fig. 4). Within the Mat Lab environment the adjustment of the parameters is done with a module that functions similarly to the neural network.

The structure of fuzzy systems achieves the following: the rigid input value – the input appurtenance functions, inference regulations - output characteristics - output appurtenance functions - output value/data.

The typically fuzzy inference systems includes a predefined regulating structure by the user who interprets the variable characterizes of the systems.

The intelligent actuator linear motion control actuator contains a microprocessor, servo amplifier, memory module, high capacity roller thrust bearing, and encoder and is supplied with a program editor and debugger.

4. THE CONFIGURATION OF THE EXPERIMENTAL STAND

In order to improve and to study the possibilities of regulating and control of the actuator movement a new research direction has been tried using complex systems of data acquiring and analysis by means fuzzy logistics. Thus a configuration has been used whose pattern is presented in Fig. 5.

As it results from the pattern in hardware configuration, there are the following components whose main characteristics are: linear actuator, traducer, and data acquisition board (number of channels, maximum speed of sampling, data transfer); account unit (microprocessor, memory, video screen), actuator interface and board of fuzzy logistics (number of fuzzy calculation rules).

The system ensures the required performances with the help of reaction coils for speed and for position (Fig. 6). The reaction coil for speed commands the acting servo engines and under the turation aspect comprises besides the engine and the amplifier, comparator and tahogenerator.

The positioning coil is made up of comparators, the amplifier, and the moving translators.

$$\varepsilon = y - y', \text{ or } \varepsilon = \frac{v}{\omega_c}, \quad (4)$$

The concrete problem refers to the use of the fuzzying is that of the projection of a system of linear positioning of the type of translation module computer programmed.

Solving the problem within a coherent theory of these quality measures is a system approximately determined between different limits.

Finally we have to eliminate the imprecision obtaining from the approximate system fuzzy a system of definite measures. From the point of view of intuitive thinking the obtained result is appreciated well than the one obtained by using the classical method exclusively with well determined numbers.

We require the projection design of a system which, at a given entrance signs should generate a positioning answer with a certain precision as close as possible to the imposed one.

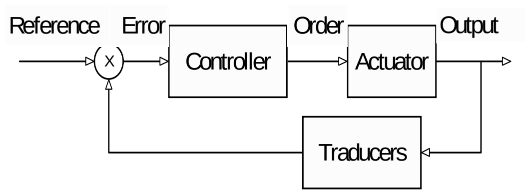

Fig. 5. The block scheme of the fuzzy regulation system.

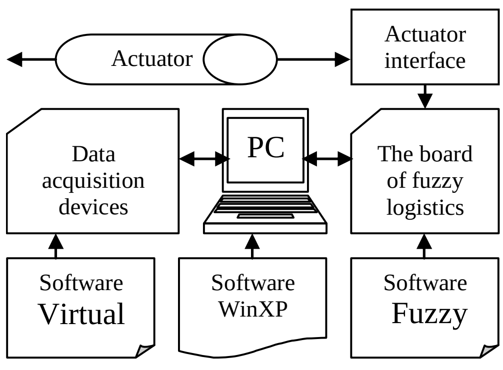

Fig. 6. The structure of the fuzzy regulation system.

Hence the initial data of design are known, the sign of entrance $X(t)$, as well as the given exit sign $Y(t)$.

The condition of design for a minimum square error of positioning is

$$\min\,[Y(t) - Y'(t)]^2, \tag{5}$$

The system of numeric control in time used even in the real time of the dynamic processes especially of the quick ones which develop in the roto-translation system, integrated components in the couple machine-tools or robots offer information of objective quality which diminish the relativity and the degree of fuzzying.

Another aspect is that of modeling these complex systems which in order to be described requires a large amount of information.

The theoretic research under the aspect of the phenomenological energetic aspect reveals the necessity of considering in a system and of informatics, respecting thus an info mechanic system. It is admitted the principle of incompatibility according to which the bigger the complexity, the smaller the possibility to the level where the precision and the relevance each other.

This type of system has at its basis some new concept where the model of representation has numbers fuzzy and which is capable of working with signs of the new type of fuzzy signs.

In order to control the process, a specialized module with data acquisition system takes over from the process of acceleration parameters and refines it by taking into account the shifts from a basis value and the dynamic of this shift.

These refined values are analyzed in the module of fuzzy logistics when the final decisions of optimization are taken into account.

The values stocked in the memory, appropriately refined, constitute the inputs of fuzzy analysis system stage that requires the implementation of interconnecting programs, data transfer and the fuzzy one.

The realization of a fuzzy controller is pursued with the introduction of the systems in the control circuits of the actuators movement, checking its functioning in real time. This superior level of high complexity will ensure the possibility of the adjustment and the extension of the results in many other fields of application in order to solve some optimization problems.

The configuration of a fuzzy regulator contains 4 main blocks: the amount of knowledge; the decision blocks (the inference engine); the fuzzy blocks which transform the input values in belonging degrees; the defuzzying blocks which transform the fuzzy results into a numerical stage of the output variants.

The introduction of the fuzzy logistic in the industrial practice of the actuators can be achieved both software can hardware.

The majority application which uses the fuzzy logistics makes use of a particular calculating program, of a standard microprocessor and microcontrollers.

The standard assembling language is completed which interactions to rapidly achieve inferences, which allow a high flexibility. In the hardware solution when a prompt answer is necessary dedicated analogical components, processors and microcontrollers with integrated fuzzy components are used.

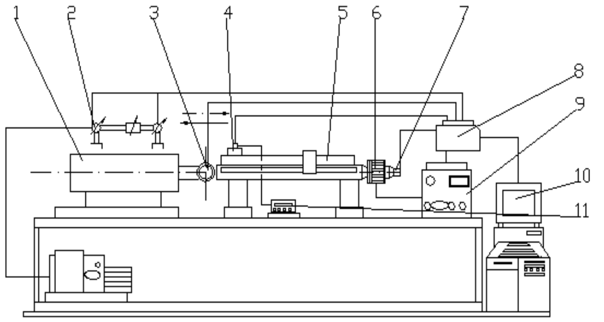

Fig. 7. The structural pattern of the modular stand of testing the actuator.

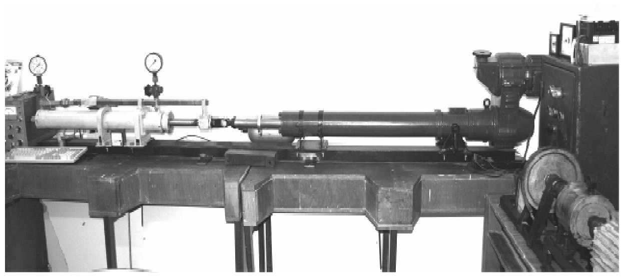

Fig. 8. The test stand for linear electro-mechanic actuator.

The structural pattern of the modular stand of testing the actuator, in the basis configuration in order to acquire the signals associated to the functional parameters of the testing process one uses momentary sensors – speed, incrementing positioning sensors and sensors of accelerometer type.

Additionally, according to the testing applications other force sensors, vibrations, temperature sensors can be introduced owing o the open modular structure. These sensors are connected a special acquisition equipment connected to the central calculator –serial interface.

The test multi parametric stand for measuring linear electro-mechanic actuator is Figs. 7 and 8 is composed of: 1 – hydraulic brake installation; 2 – pressure transducer; 3 – force transducer; 4 – displacement transducer; 5 – optical ruler; 6 – linear actuator; 7 – speed transducer; 8 – data acquisition board; 9 – power measuring kit; 10 – computer; 11 – display device. 12 – support.

5. CONCLUSIONS AND OUTLOOK

An experimental stand has been designed meant to lead by means of fuzzy logics a linear positioning system, which achieves the load control throughout the working cycle.

The paper presented a series of factors which recommend the implementation of the fuzzy logistics on the linear actuators as well as the structure of the experimental stand.

The positioning precision of the actuators can be improved if within the components of the regulating systems a fuzzy regulator is placed.

Searching the interferences of the statistic modeling, especially those linked to establishing the relations of representation of the experimental data resulted from measures with the theory of the vague multitudes and of the fuzzy logics reveals some of the conclusions which are further mentioned.

In the mathematic working of the experimental data and the vague multitudes we work constantly with approximate values. Both theories operate in the processes of logistics reasoning with similar procedures through actions of fuzzying and defuzzying.

The statistic modeling and the fuzzy modeling interfere giving birth to perspectives of the development of both subjects through reciprocal extrapolation of procedures, methods, techniques and methods of solving. In the problems of optimization, both theories are based on the optimizations through the method of minimizing the medium square errors towards the desired parameter.

Searching for the best situation is made through the method of maximum ramp. The methods based on the theory fuzzy are better than the usual numeric method because it uses the approximate measure instead of those determined to obtain a fuzzy characteristic equal to a correspondence of normal size. The desired characteristic transformed in fuzzy ramp has several degrees of freedom and is more adaptive.

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.

The development perspectives aim optimum solutions equipped with mechanisms of transmission and movement transformation with high efficiency and fiability.

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