ESTIMATION OF THE MATHEMATICAL MODEL OF THE DC MOTOR COUPLED WITH A REACTION WHEEL BASED ON THE GENETIC ALGORITHM

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Abstract: In this paper, it was proposed the experimental identification of the mathematical model of the DC motor, coupled with a reaction wheel. It was proposed to approximate the experimental curve with the mathematical model of order 2 inertia, identified by Genetic Algorithm. To estimate the mathematical model of the control object it was proposed to use the Genetic Algorithm method, the results obtained were compared with the Strejc methods and the results obtained using the Process Model's module from System Identification Toolbox from MATLAB.

KEYWORDS: MODEL, EXPERIMENTAL IDENTIFICATION, GENETIC ALGORITHM, DC MOTOR.

1. Introduction

Industrial processes can be classified into information and technological processes. The operations are carried out at the technological installations and involve mass and energy transfer. The underlying technological process is the development of electric cars, which represent actuators, most often operate on the basis of electromagnetic forces.[1-4]

Depending on the type of electric current that starts the engines, they can be classified into: DC motors and AC motors. DC motors are the most commonly used motors as actuators in control systems because of their linear characteristics and relatively simple speed control methods [5].

The mathematical model of the industrial process description in automation is necessary to solve the problem of regulation.

Knowing the mathematical model of the industrial process requires the use of identification procedures. The identification of the industrial processes represents the estimation of the parameters and the structure of the mathematical model, ensuring the best coincidence of the output signal from the model with the process [6]. In the process of introducing the same input signal, where the physical process is considered as an entity, seen as a black box with unknown internal structure.

Experimental identification involves the acquisition of experimental data in real time. Thus the experimental variation of the DC speeds at the reference speed of 8500 rpm is shown in figure 1.

![Fig.1. The experimental variation of the DC speeds at the reference speed of 8500 rpm](image-url)
2. Results and discussions

To estimate the mathematical model of the control object it was proposed to use the module Process Models from System Identification Toolbox from MATLAB.

It was proposed to approximate the control object with three types of the mathematical models: model of object with first order inertia (1) and (4); model of object with second order inertia (2); model of object with third order inertia (3)[7-8].

\[ H_1(s) = \frac{0.98006}{2.9173s+1} \]  
\[ H_2(s) = \frac{1.0069}{3.1695s^2 + 5.02899s + 1} \]  
\[ H_4(s) = \frac{4.2292}{19044.8s^4 + 37394.9s^3 + 5713.25s^2 + 1} \]  
\[ H_4(s) = \frac{2132.75}{4.31s + 1} \]  

Where (4) is the approximate model of object with first order inertia using Strejc method.

The comparison of the results is shown in figure 2, where 1 – curve is experimental curve, 2 - curve is transient process obtained for (1) identified model, 3 - curve is transient process obtained for (2) identified model, 4 - curve is transient process obtained for (3) identified model and 5 - curve is transient process obtained for (4) identified model.

The obtained results do not have a good approximation accuracy, and this is shown in figure 2.

![Fig.2. Transient processes: 1 – the experimental curve; 2, 3, 4 and 5 – curves, the transient processes of models, respectively (1), (2), (3) and (4).](image)

For this reason, has been selected a new method of identifying the mathematical model through successive iterations.

A genetic algorithm simulates the evolution of the model to produce "offspring" (the next iteration value), that is, the next level of setting parameters, with the desired characteristics.

Process configuration parameters, for example speeds, pressures, etc. for each series of tests, they are encoded in series of binary digits, called chromosomes. A randomly generated set of distinct chromosomes forms an initial population. These chromosomes are produced to determine the product characteristics that are used to calculate the total capacity of the product (which is desirable) that results from the chromosome parameter settings [3].

Because the pairing of the chromosomes to produce offspring is more likely among the parents with a higher strength than the parents with a lower decrease, the average number of successive generations will increase, and the optimal set of bit patterns (or schematics) will be found for the chromosome, from which gives the optimal parameter settings[9]. Changes as patterns evolve are caused by the two main genetic operators, crossover and mutation. In the crossover, a random point is taken on the chromosome line, at which the sections are changed after the point.

Also, under a stochastic function there would be a mutation of one or more binary digits (bits) at random positions on the chromosome string. Since crossover is related to mating and thus to test chromosomes, a high probability of crossover will encourage the constant climb of the hills to the optimal set of parameter values[10-12]. On the other hand, a high mutation rate will lead to more searching of the less promising parts of the data space. This can be used to optimize problems where a number of sub-optimal performance peaks can be avoided [13].

In this case, the chromosomes will be considered as the parameters \( k \), \( T_1 \) and \( T_2 \) of the model of the object of inertia of the second order

\[ H(s) = \frac{k}{(T_1s+1)(T_2s+1)} \]  

After 213 iterations we obtain the following values for parameters \( k \), \( T_1 \) and \( T_2 \):

\[ k = 1.01517 \]
\[ T_1 = 3.9323 \]
\[ T_2 = 0.3895 \]

The following model of object with second order inertia is obtained:
\[ H_s(s) = \frac{1.01517}{1.53199s^2 + 4.3219s + 1} \] (6)

The transient process of the model obtained by using the genetic algorithm is represented in figure 3. So, we observe a relatively good approximation of the model that has the absolute error of 1.55%.

Fig.3. Transient process of the approximate model using the genetic algorithm

Conclusions:
1. In the analyzed case, the process had only 3 controllable factors. It is accepted that processes with a greater number of controllable factors would involve a larger series and therefore a larger number of iterations.
2. Regarding the efficiency of the genetic algorithm method, the experimental identification technique reached an optimum of 1.55%, compared to the other methods which have an absolute error of more than 10%.

References:
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