LOGICAL NETWORK DESIGN OF MICROBEARING SYSTEMS

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Abstract

This paper presents the some applications of logical network analysis in topological form as an Artificial Neural Networks (ANN) intelligence component implemented regard to the optimum calculations of micro-bearing operating parameters such as hydrodynamic pressure, carrying load capacity, and optimum measurements of friction forces, friction coefficient and micro-bearing wear.
Efficient functioning of slide micro-bearings systems require to choice the proper journal shapes, bearing materials, roughness of bearing surfaces and many other features to which belongs capability to the processes and control. Artificial intelligence of micro-bearing leads to the creating and indicating of the network logical models to describe most simple and most proper topological graphical schemes presenting the design of anticipated processes. Application of the logical network analysis into the micro-bearing HDD design is the subject-matter of this paper. Mechanism of neuron activity, basic scheme of detection system in modern of Atomic Force Microscope, tip radius estimation, input impulse, tribo-topology logical network scheme mechanism, tribo-topology logical network analysis scheme mechanism, the pressure distributions in cylindrical micro-bearings caused by the rotation in circumferential direction and magnetic field, the view from the film origin and from film end are presented in the paper.

Keywords: *artificial neural network, propositional calculus application, optimum of solutions*

1. Artificial Neural Network Intelligence components

Artificial Neural Network supported by the propositional calculus includes in the very complicated HDD microbearing calculations as well in roughness measurements of very small microbearing cooperating surfaces in micro and nano level. In mentioned calculations and measurements is necessary the optimum strategy of computer science program performances [1, 2]. Artificial Neural Network Analysis supported by the propositional calculus presented in this paper establishes a proper tool of highly applied mathematical knowledge. Subfields of Logical Network Analysis (LNA) in the field of micro-bearing systems are organized around following particular problems:

- the collection of the data referring anticipated micro-bearing properties and features which are necessary for right functioning of the designed devices,
- determination of the input and output data for anticipated for intelligent mechanism design,
- indication of signal flow direction,
- the applications of propositional calculus analysis to the intelligent control theory and cyber-bio-tribology,
- presentation of the most simplified graphical scheme of performed propositional calculus chart.

2. Examples of control systems

The mechanism of an Artificial Neural Network Activity is shown in Fig. 1. Mentioned mechanism includes:

- input element which is then weighted,

- the summing block,
- actuator,
- output element.

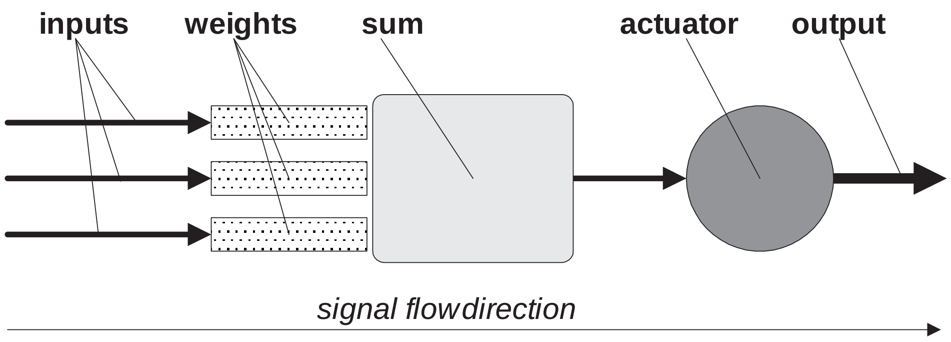


Fig. 1. Mechanism of neuron activity

Micro-bearing systems have multi-dimension space of input data. But depending on dynamic conditions of designed micro-bearing, the numerous input data can be divided into three groups:

1. Computer Ventilator Micro-bearing to 3000 rpm,
2. HDD-microbearing to 5000 rpm,
3. HDD-microbearings above 5000 rpm.

After some modification of the AFM scanning microscope units such measurements could be performed directly in a b in micro-mechanism devices. The proposed technique will make it possible to characterize more precisely friction features in the conditions very close to those usually met in conventional devices.

One of the important advantages of the AFM microscope application in the area of investigations with the use of micro-bearing surface measurements is the possibility of carrying out measurements directly in liquid, namely that which surrounds the cells or micro- bearing gaps.

The mean statistical height of the roughness amounts to 20 nm (Fig. 2b). In the cross-section shown in Fig. 2c the characteristic vertical and lateral asperities of the roughness, reaching the dimensions of 15 – 25 nm, can be observed. The values correspond to the dimensions of material cells.

3. Propositional tools of the Logical Network Measurements and Design

Here are presented the propositional tools of Logical Network of Measurements and Design (LNMD) occurring in HDD micro-bearing [7], [8], [9]. Input and output impulses are defined in the form of elements occurring in propositional calculus.

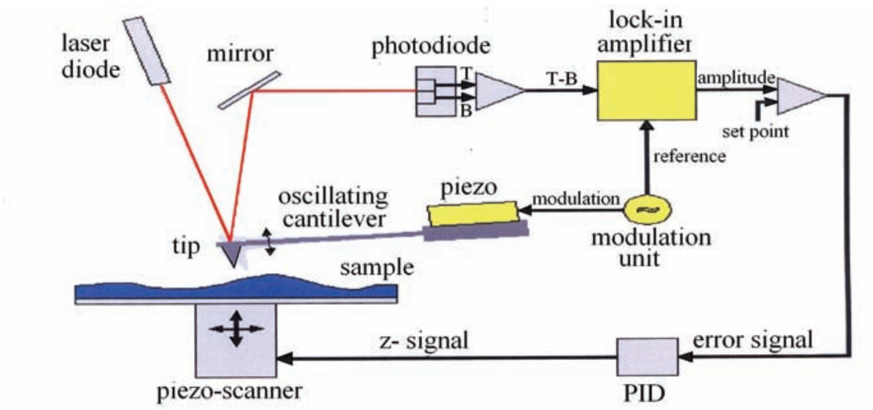
We assume the following nods as connection boxes:

$\vee$ - sum mechanism,
$\wedge$ - intersection mechanism which choices common properties of two impulses,
/ - mechanism which negates each impulse.

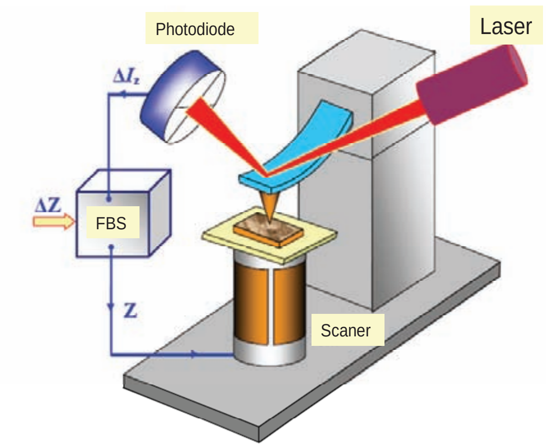
We denote following notations for considered impulses:

x, y - input impulses as elements of propositional calculus,
z - output impulses as elements of propositional calculus,
1 - the space of all possible impulses,
0 - empty impulse.

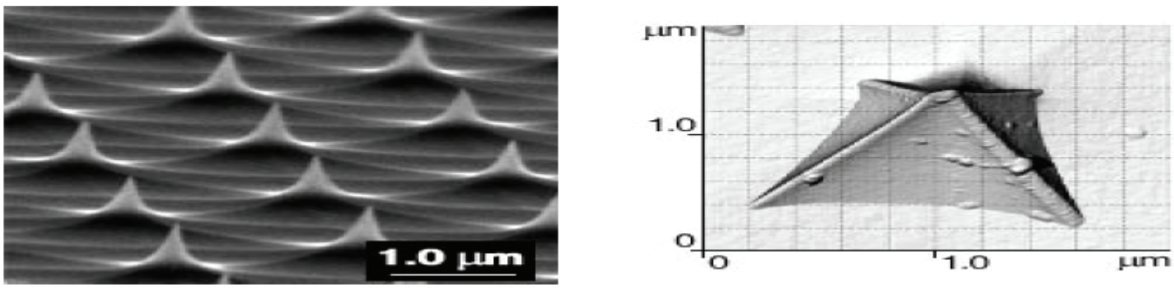
Above mechanisms of Logical Network are presented and explained in Fig. 2. Fig. 2a, b, c show the general mechanisms. Fig. 2d, e, f, g, h, i, j illustrate the particular cases of logical mechanism action for 0 and 1 impulses. Fig. 2k, m, n, o, p, q, r present the cases of mechanisms action for arbitrary impulse w. The nods: sum, intersection and negation mechanism are representing the AI tools.



a)



b)



c)

Fig. 2. Atomic Force Microscope (AFM): a) basic scheme of AFM, b) detection system in modern AFM, c) tip radius estimation

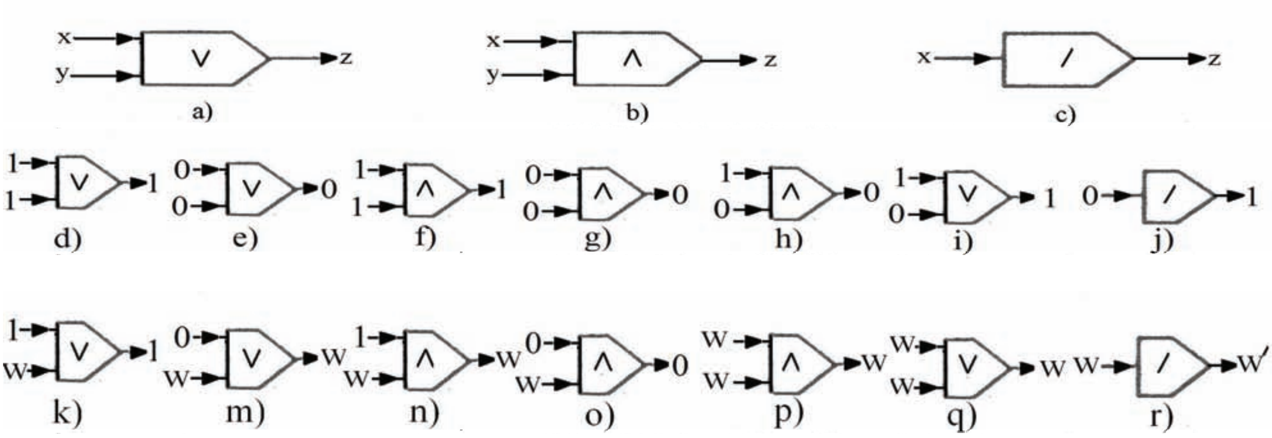


Fig. 2. Input impulse x and y going into nods and output impulse z outgoing from the nods

4. Examples of tribo-topology network analysis

Now for a one device the value of the vector **U** presents the following expression:

$$U(x,y,w,v)=[(x\vee w)^{/}\wedge y]\vee\{[(w^{/}\wedge y)\vee v]\wedge x\}\vee(x\wedge v), \tag{1}$$

where:

x, y, w, v - input impulses where $x\in X$, $y\in Y$, $w\in W$, $v\in V$,

z=U(x,y,w,v) - output impulse of considered device.

Tribo-topology scheme of mechanism presented by the formula (4) leads from input x, y, w, v to the output impulse z. By virtue of the propositional calculus theory the expression (4) we can transform in following form [4]:

$$U=[(x\vee w)^{/}\wedge y]\vee\{[(w^{/}\wedge y)\vee v]\wedge x\}\vee(x\wedge v)\equiv$$

$$\equiv[x^{/}\wedge(w^{/}\wedge y)]\vee\{[(w^{/}\wedge y)\wedge x]\vee(x\wedge v)\}\vee(x\wedge v)\}\equiv$$

$$\equiv[x^{/}\wedge(w^{/}\wedge y)]\vee[(w^{/}\wedge y)\wedge x]\vee(x\wedge v)\equiv$$

$$\equiv(x^{/}\vee x)\wedge(w^{/}\wedge y)\vee(x\wedge v)\equiv$$

$$\equiv 1\wedge(w^{/}\wedge y)\vee(x\wedge v)\equiv$$

$$\equiv(w/\wedge y)\vee(x\wedge v). \tag{2}$$

Result is as follows:

$$U(x,y,w,z)\equiv(w/\wedge y)\vee(x\wedge v). \tag{3}$$

Symbol 1 denotes total impulses space.

In practical case we have a lot of input impulses. Logical Network scheme corresponding to the formula (3) is presented graphically in Fig. 3.

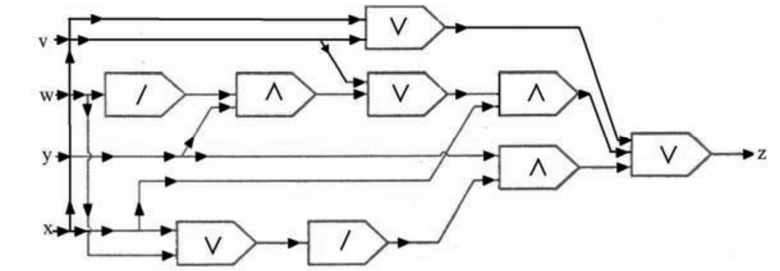


Fig. 3. Tribo-topology logical network scheme mechanism: $U=[(x\vee w)/\wedge y]\vee\{[(w/\wedge y)\vee v]\wedge x\}\vee(x\wedge v)$ for eight connections

By virtue of the propositional calculus theory the mechanism U of in input impulses x, y, w, v defined by Eq.(1) after logical transformations (2) tends to the output impulse z in the form (3) and is showed in the following graphical form in Fig. 4.

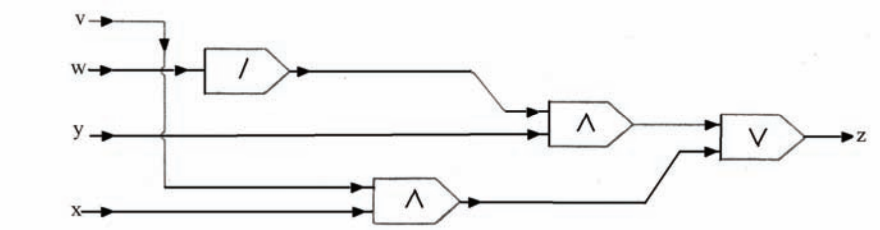


Fig. 4. Tribo-topology logical network analysis scheme mechanism: $U(x,y,w,v)\equiv(w/\wedge y)\vee(x\wedge v)$ for three connections

It is visible that in this case the equivalent scheme presented in Fig. 4 is more simple than the origin scheme presented in Fig. 3 because in the first case we have eight connections between variable nods (boxes), however second case has only three. Less numbers of connections denotes more proper und more productive network for calculation problem.

During the slide bearing and especially HDD micro bearing calculations we had been used and utilized the sequence of various mutually connected data of experimental AFM measurement results. The most simple geometry and sequence logical architecture of connections of used data impulses have the important influences on the convergence of computer calculations of necessary exploitation parameters. Hence follows the weightiness of the proposed solution in comparison to the others methods. More examples of the proposed system had been described in the last authors' research team papers [8-10].

5. Logical Network Architecture in micro-bearing design

To obtain hydrodynamic pressure values as output impulse z occurring in HDD micro-bearing gap we take into account the following input impulses:

- x_1, x_2, x_3, … regarding cylindrical, spherical, conical,… journal shapes respectively,
- y_1, y_2 regarding grooves and ridges located on the journal and sleeve surface respectively,
- w_1, w_2, w_3, … regarding shapes of the mentioned grooves and ridges respectively,
- v_1, v_2 regarding roughness located on the journal and sleeve surface respectively,
- s_1, s_2, s_3, s_4, … regarding non-stochastic or stochastic stationary or non-stationary modified Reynolds Equations for variable or constant values of dynamic oil viscosity η and pressure p in gap height direction. Output impulse z consists of the following sub-impulses z_1, z_2, z_3, z_4 namely optimum load carrying capacity, minimum friction forces, minimum friction coefficient, minimum wear. The formulae presenting the Lame' coefficients introduced in modified Reynolds equation for various micro-bearing journals enable to seek and to find the shapes of micro-bearing surfaces with grooves for the optimum load carrying capacities. The author indicates the similarity between the intelligent micro-bearing properties and the intelligent behaviour of human bio-bearings and other living joints [8, 9]. The field Artificial Intelligence (AI) was founded on the claim that a central property of human beings, intelligence can be so precisely described that it can be simulated by a machine. Artificial intelligence has been the subject of intelligent agents and today become an essential part of the technology industry, providing the heavy lifting for many of the most difficult problems in computer science [6]. AI research is highly technical knowledge.

Using the network analysis theory in this paper was established the method of minimum wear and micro-bearing friction forces determination during the exploitation process.

6. Numerical tools applied for micro-bearing load carrying capacity calculations

The pressure distributions in cylindrical slide micro-bearings and bio-bearings are determined in the lubrication region Ω_d, which is defined by the following inequalities: $0 \le \varphi \le \varphi_k$, $-b_d \le z \le b_d$, where $2b_d$ – micro-bearing length.

Numerical calculations are performed in MATLAB 7.3 Professional Program by virtue of the above mentioned logical network procedure by means of the finite difference method (see Fig. 5). Gap height of the cylindrical micro-bearing and bio-bearing has the following form:

$$\varepsilon_T = \varepsilon(1 + \lambda_{cy} \cos\varphi), \tag{4}$$

where:

λ_{cy} - eccentricity ratio in cylindrical micro-bearing,

ε - radial clearance in cylindrical micro-bearing or bio-bearing.

From performed calculations are obtained the pressure distribution in cylindrical micro-bearing gap caused by the rotation taking into account magnetic field for dimensionless magnetization susceptibility χ=1.50, dimensionless magnetic coefficient of ferro-lubricant viscosity δ_{B1}=0.20 and magnetic number $R_f = N_o B_o / p_o$=0.50.

By virtue of boundary of modified Reynolds conditions the angular coordinate of the film end has the values: φk=3.654 rad, φk=3.679 rad, φk=3.698 rad. From the numerical calculations it follows, that magnetic induction field increases the micro-bearing capacities by 6 percent at least, and– in some cases– even 10 percent.

Figure 5 presents pressure distribution and loads carrying capacity in micro-bearing as a one component of the output vector by virtue of the numerical calculations [5] of modified Reynolds equation performed in MATLAB 7.6 Professional Program.

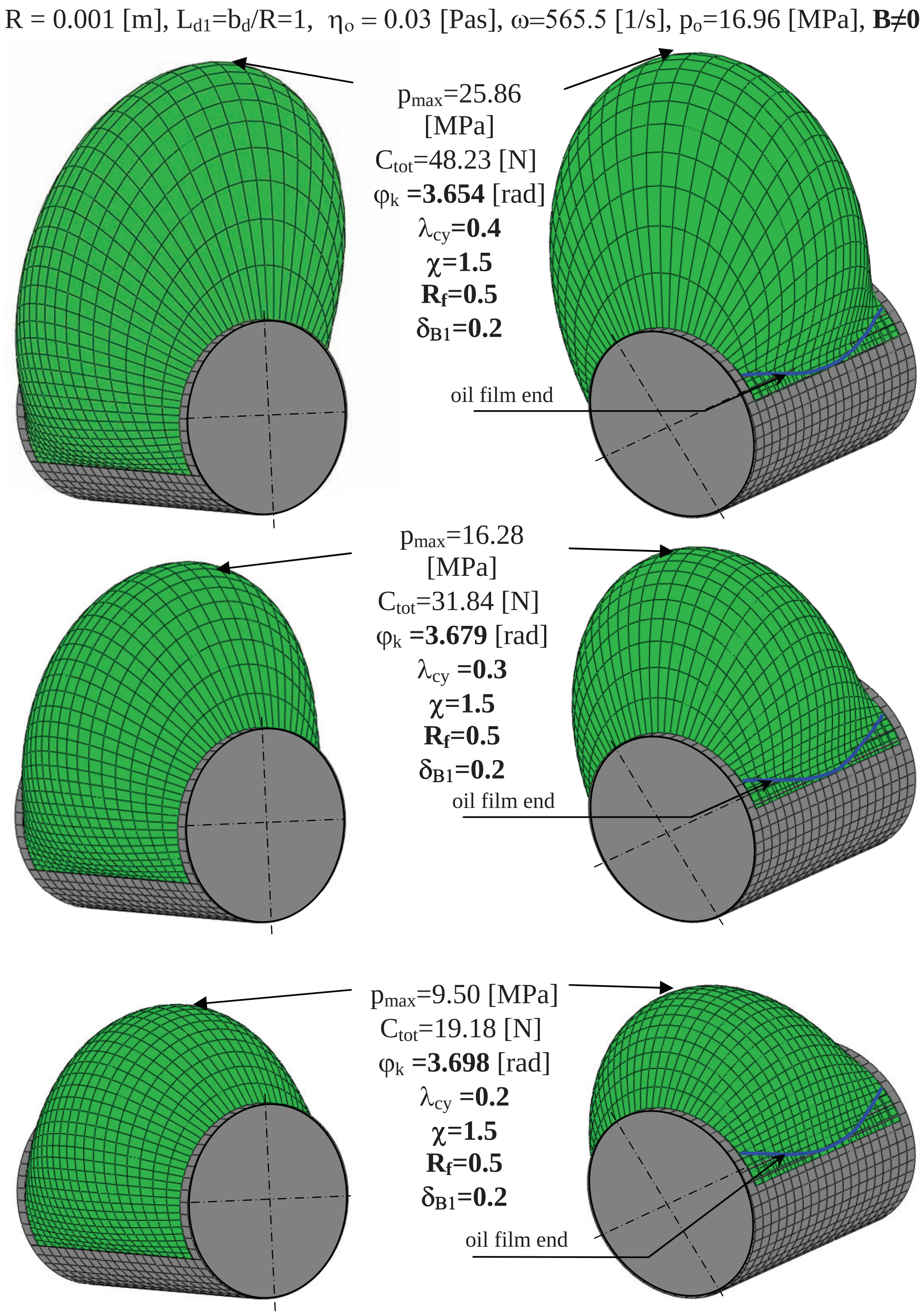


Fig. 5. The pressure distributions in cylindrical micro-bearings caused by the rotation in circumferential direction and magnetic field. Left side presents the view from the film origin, right side shows the view from film end

7. Final results

Corollary 1. Final result of logical network system application is defined as a union of obtained output impulses

Corollary 2. The final calculation indicator with the sum of output impulses having the least sum of connections is a most productivity logical network of data presented journal bearing design and in the case of identification of journal bearing work parameters using acoustic emission methods.

Corollary 3**.** Taking into account influences of variable sometimes mutually depended impulses on the behaviour of slide journal bearing system, we can investigate how the design variables of mentioned bearings affect the bearing stiffness and the natural frequencies of the bearing shaft [8-10].

Corollary 4**.** This research also shows that the supporting structure which includes the stator, housing and base plate plays an important role in determining the natural frequencies and mode shapes of slide journal bearing system [8-10].

8. Conclusions

Results obtained in this paper in the field of logical network analysis for data transmission impulses during journal bearing design presented in graphical form as a mathematical propositional calculation theory implementation constitute new convenient tools of artificial intelligence methods and computer calculation methods occurring in maritime transport [8-10].

Presented paper establishes the scheme of calculation algorithm of hydrodynamic pressure and carrying capacity changes in journal-micro-bearings for various journal shapes and for various geometries.

The above mentioned results enable to investigate the dynamic behaviour of journal micro-bearing system by solving Reynolds equation and the equations of motion in some degree of freedom. It shows that the dynamic journal micro bearing can be affected not only by the design variables but also by already existing motor parameters [8-10].

Acknowledgement

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