NETWORK ANALYSIS FOR ARTIFICIAL INTELLIGENT MICRO-BEARING SYSTEMS

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Abstract

This paper presents the some implementation of network analysis in logical, topological form as a artificial intelligence component applied for determination of optimum system design regard to the micro-bearing operating parameters such as carrying load capacity, 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 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.

Logical network analysis in graphical form as a mathematical implementation for intelligent micro-bearing numerical calculations is presented in this paper. Presented paper establish the scheme of calculation algorithm of hydrodynamic pressure and carrying capacity changes in micro-bearings for various journal shapes and for various geometries.

Keywords: *network analysis, choice process simulation, most proper scheme*

1. Network analysis in micro-bearing systems

Artificial intelligence supported by the logical network analysis includes in the technology industry, and in many of the most difficult problems connected with optimum strategy of computer science program performances [1, 2]. Network analysis for Artificial Intelligence (AI) research is highly applied mathematical knowledge. Subfields of Logical Network Analysis (LNA) in the field of micro-bearing systems are organized around following particular problems:

- the creating of models of LNA for computer calculations taking into account the graphical scheme tools [7],
- the study of simplification of the Logical Network Analysis Scheme (LNAS) by virtue of graphical topology and attempt to create of the equivalence of Logical Network Analysis Scheme $(LNAS)_{eq}$ using the logical set theory and topology laws [3, 4],
- the applications of logical network analysis to the intelligent control theory and cyber-bio-tribology.

2. Input and Output electronic impulses

Logical Network Analysis Scheme (LNAS) is a member of Artificial Intelligence (AI) of micro-bearing systems. LNAS is beginning from electronic input impulses and is finished in output electronic impulses.

Sometimes in particular cases we can observe the Inverse Control Systems (ICS) for example in structure of neural network [8] and learning algorithms occurring for example in bioreactor see Fig. 1.

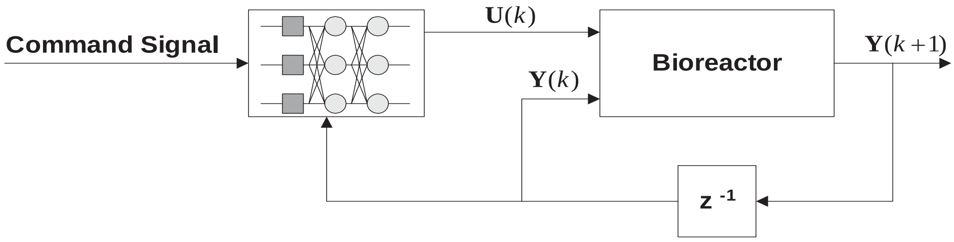

Fig. 1. Control system based on ICS, where U- input vector, Y-output vector

Micro-bearing systems have multi-dimension space input vector in following form:

$$\mathbf{U}(A, B, C, D, \ldots, \Gamma_1, \Gamma_2, \Lambda_1, \Lambda_2, \ldots, \Pi_1, \Pi_2, \ldots). \quad (1)$$

The components in such vector regard to the geometrical journal and sleeve shapes are as follows: A – cylindrical shape of the journal, B – conical shape of the journal, C – spherical shape of the journal, D – parabolic shape of the journal, E – hyperbolic shape of the journal, F – grooves and ridges located on the sleeve surface, F – grooves and ridges on the journal surface, … Γ_n – various magnitudes of micro-bearing surface roughness for n = 1, 2,…, Λ_n – various magnitudes of radial clearances for n = 1, 2,…. Regard to the method of calculations we have: Π_1 – non-stochastic stationary modified Reynolds Equations for variable values of dynamic oil viscosity η and pressure p in gap height direction α_2, Π_2 – stochastic non stationary (time t dependent) modified Reynolds Equations (2) for constant values of dynamic oil viscosity η and pressure p in gap height direction α_2:

$$\frac{1}{h_1}\frac{\partial}{\partial\alpha_1}\left[\frac{E\left(\varepsilon_T^3\right)}{\eta}\frac{\partial E(p)}{\partial\alpha_1}\right]+\frac{1}{h_3}\frac{\partial}{\partial\alpha_3}\left[\frac{h_1}{h_3}\frac{E\left(\varepsilon_T^3\right)}{\eta}\frac{\partial E(p)}{\partial\alpha_3}\right]=6\omega h_1\frac{\partial E(\varepsilon_T)}{\partial\alpha_1}+12h_1\frac{\partial E(\varepsilon_T)}{\partial t}. \quad (2)$$

where:
E - expectancy operator,
ε_T - the total micro-bearing gap height,
ω - journal angular velocity.

The output electronic impulse vector has the form:

$$\mathbf{Y}(p,c,f_R,\mu,w), \quad (3)$$

where:
p - hydrodynamic pressure,
c - load carrying capacity,
f_R - friction forces,
μ - friction coefficients,
w - micro-bearing wear.

3. Tools of the Logical Network Analysis Scheme

Here are presented the tools of LNAS occurring in micro-bearing electronic network and in computer science [7-9].

We assume the following nods as connection boxes:
∪ - union (sum) mechanism,
∩ - intersection mechanism which choices common properties of two impulses,
~ - mechanism which negates each impulse.

Above mechanisms are presented and explained in Fig. 2.

The nods: sum, intersection and negation mechanism are representing the AI tools.

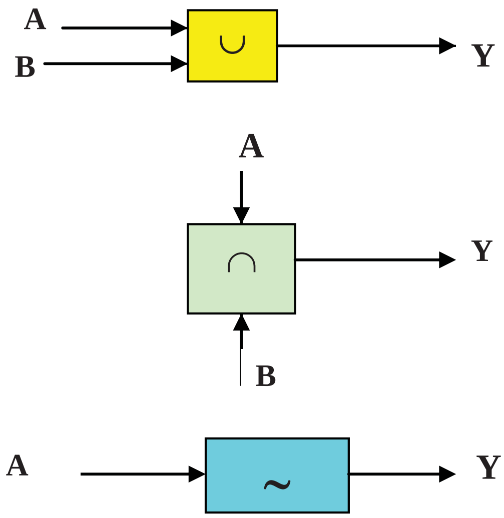

Fig. 2. Input impulse A and B going into nods and output impulse Y outgoing from the nods

4. Examples of tribo-topology network analysis

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

$$U(A,B,C,D)=[\sim(A\cup C)\cap B]\cup\{[(\sim C\cap B)\cup D]\cap A\}, \quad (4)$$

where:
A, B, C, D - input impulses,
U(A,B,C,D) - output impulse vector of first kind.

Tribo-topology scheme of $(LNAS)_1$ mechanism presented by the formula (4) which leads to the output impulse is given graphically in Fig. 3.

By virtue of the set theory the expression (4) we can transform in following form [4]:

$$\begin{aligned} &U\equiv[\sim(A\cup C)\cap B]\cup\{[(\sim C\cap B)\cup D]\cap A\}\equiv \\ &\equiv[\sim A\cap(\sim C\cap B)]\cup\{[(\sim C\cap B)\cap A]\cup(A\cap D)\}\equiv \\ &\equiv[\sim A\cap(\sim C\cap B)]\cup[(\sim C\cap B)\cap A]\cup(A\cap D)\equiv \\ &\equiv(\sim A\cup A)\cap(\sim C\cap B)\cup(A\cap D)\equiv \\ &\equiv X\cap(\sim C\cap B)\cup(A\cap D)\equiv \\ &\equiv(\sim C\cap B)\cup(A\cap D). \end{aligned} \quad (5)$$

Result is as follows:

$$U(A,B,C,D)\equiv(\sim C\cap B)\cup(A\cap D). \quad (6)$$

Symbol X denotes total impulses space.

In Fig. 4 the mechanism U of in input impulses A, B, C, D as the result (6) which tends to the output impulse Y is showed in the graphical form.

It is visible that in this case the equivalent scheme $(LNAS)_{1eq}$ presented in Fig. 4 is more simple than the origin scheme $(LNAS)_1$ presented in Fig. 3 because $(LNAS)_1$ has seven connections between two variable nods (boxes), however $(LNAS)_{1eq}$ has only three.

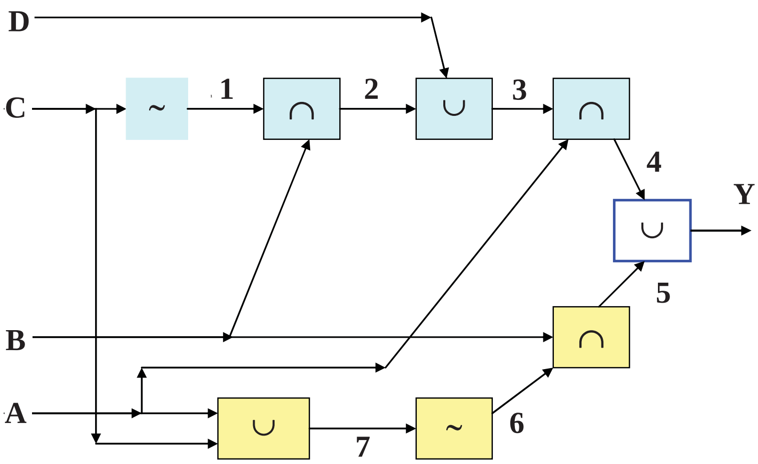

Fig. 3. Tribo-topology logical network scheme (LNAS)$_1$ mechanism: U=[~(A∪C)∩B]∪{[(~C∩B) ∪D]∩A} for seven connections

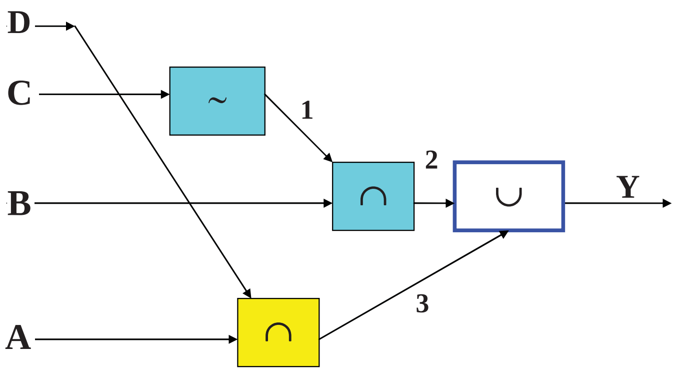

Fig. 4. Tribo-topology logical network analysis scheme (LNAS)$_{1eq}$ mechanism: U≡(~C∩B)∪(A∩D) for three connections

Less numbers of connections denotes more proper und more productive network for calculation problem. Taking use from the other input electronic impulses of second kind we take into account the next output impulse in following vector form:

$$\mathbf{U}(\Gamma_1,\Gamma_2,\Lambda_1,\Lambda_2), \tag{7}$$

and the value of the vector we assume following expression:

$$U=[\sim(\Gamma_1\cap\Gamma_2)\cup\Lambda_1]\cap[\sim(\Lambda_1\cup\sim\Lambda_2)\cap\Gamma_1], \tag{8}$$

where Γ_1, Γ_2, Λ_1, Λ_2 - input electronic impulses.

Expression (8) on the ground of the simple set theory we can transform in following form:

$$\begin{gathered} U\equiv[\sim(\Gamma_1\cap\Gamma_2)\cup\Lambda_1]\cap[\sim(\Lambda_1\cup\sim\Lambda_2)\cap\Gamma_1]\equiv \\ \equiv(\sim\Gamma_1\cup\sim\Gamma_2\cup\Lambda_1)\cap(\sim\Lambda_1\cap\Lambda_2\cap\Gamma_1). \end{gathered} \tag{9}$$

Result is as follows:

$$U(\Gamma_1,\Gamma_2,\Lambda_1,\Lambda_2)\equiv(\sim\Gamma_1\cup\sim\Gamma_2\cup\Lambda_1)\cap(\sim\Lambda_1\cap\Lambda_2\cap\Gamma_1). \tag{10}$$

A new Tribo-Topological scheme of network (LNAS)$_2$ mechanism described by the formula (9) is presented in Fig. 5.

In Fig. 6 is presented the equivalent scheme (LNAS)$_{2eq}$ mechanism described by the formula (10) for Γ_1, Γ_2, Λ_1, Λ_2 - input impulses which tends to the Y - output impulse.

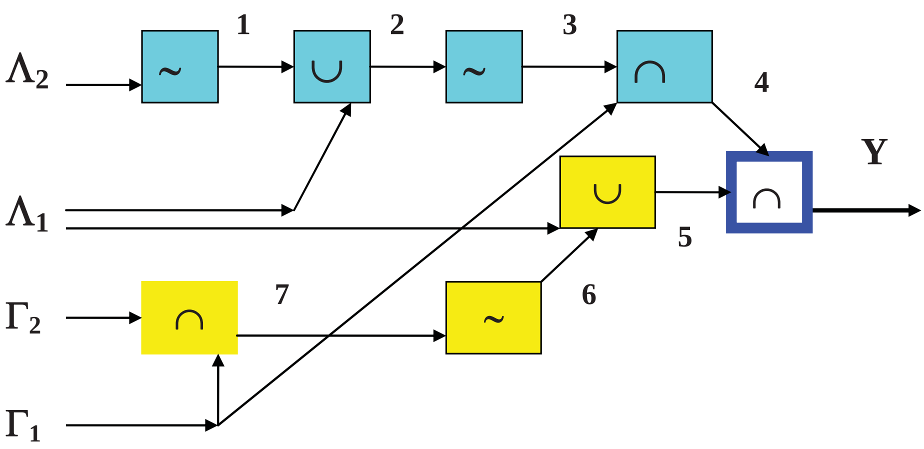

Fig. 5. Tribo-topology logical network scheme (LNAS)$_2$ mechanism $U=[\sim(\Gamma_1\cap\Gamma_2)\cup\Lambda_1]\cap[\sim(\Lambda_1\cup\sim\Lambda_2)\cap\Gamma_1]$ for seven connections

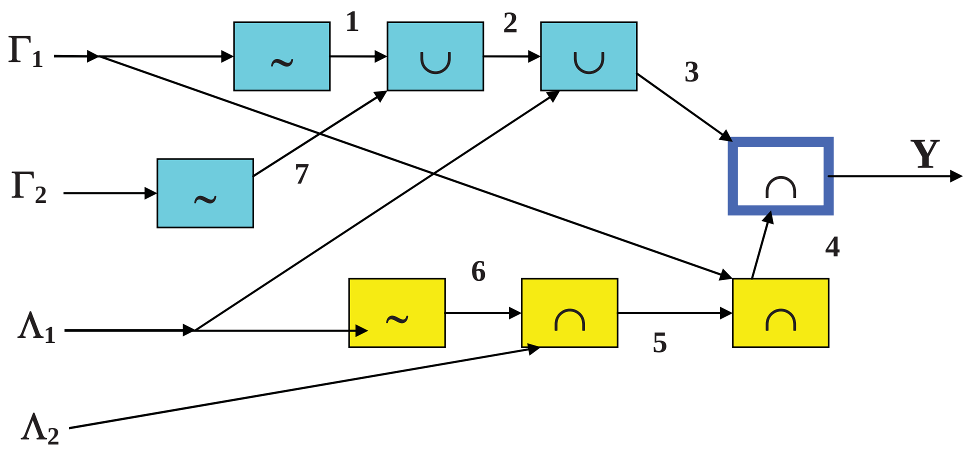

Fig. 6. Tribo-topology logical network scheme (LNAS)$_{2eq}$ mechanism $U\equiv(\sim\Gamma_1\cup\sim\Gamma_2\cup\Lambda_1)\cap(\sim\Lambda_1\cap\Lambda_2\cap\Gamma_1)$ for seven connections

It is visible that in this case the scheme (LNAS)$_1$ of origin network presented in Fig.5 and the equivalent scheme (LNAS)$_{2eq}$ presented in Fig 6 have the same number of connections.

5. Load carrying capacity

The formulae presenting the Lame` coefficients in modified Reynolds equation (2) 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.

Figure 7 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 (2) performed in Matlab 7.6 Professional Program.

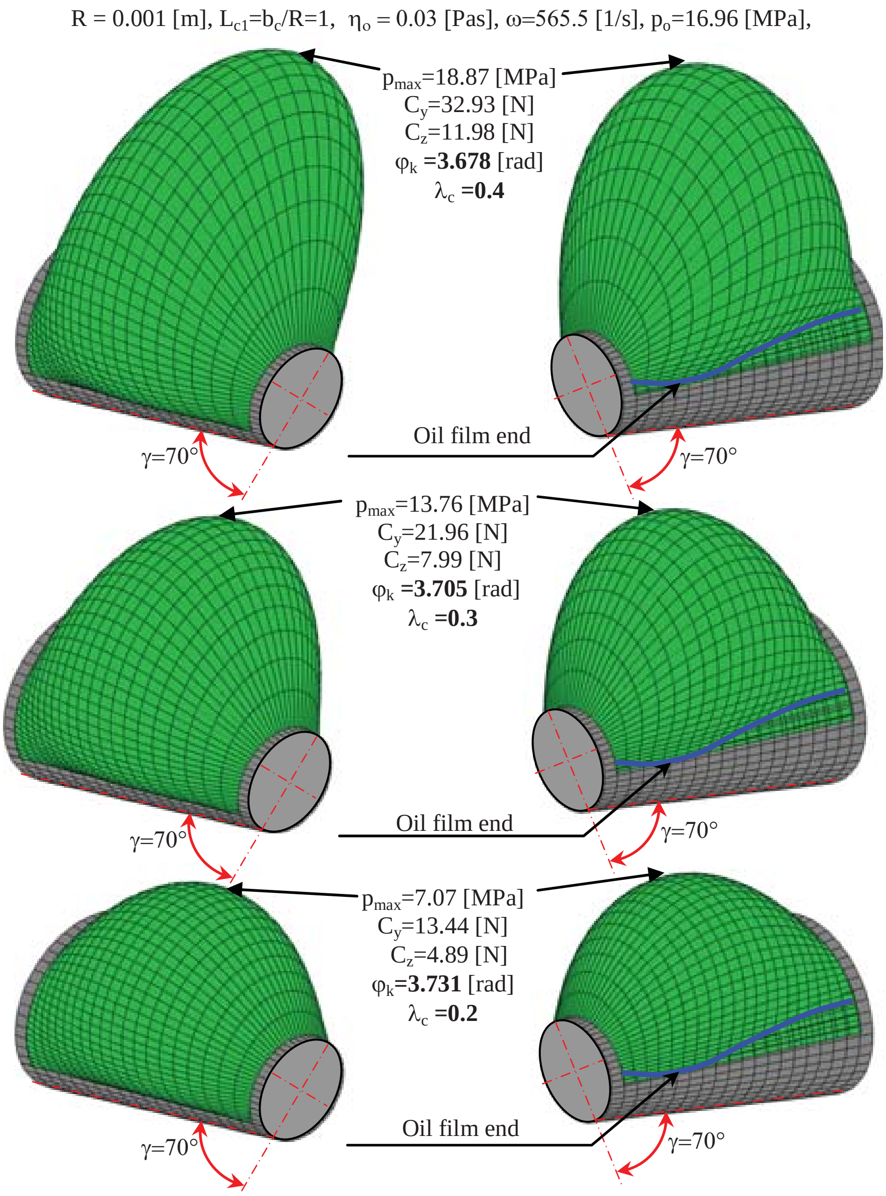

Fig. 7. The pressure distributions in conical micro-bearings caused by the rotation in circumferential direction where conical inclination angle γ=70°. Left side presents the view from the film origin, right side shows the view from film end. Notations: p_{max} – maximum pressure; C_z,C_y – load carrying capacity components, λ_c – relative eccentricity, R – radius of the cone, b_c – bearing length, ω – angular velocity, η – oil dynamic viscosity

6. Final results

Corollary 1.

Final calculation indicator Y_F a union of particular output impulses: Y_1,Y_2,… is defined as the limit of the sum logical network output mechanisms namely of the two output impulses of two kinds of networks and the third network kind of partial modified differential Reynolds equation for pressure and carrying capacity distribution. Such indicator is defined in the following form:

$$Y_F \equiv Y_1 \cup Y_2 \cup .... \Leftrightarrow U(A,B,C,D,E,F,...) \cup U(\Gamma_1,\Gamma_2,\Lambda_1,\Lambda_2) \cup U(\Pi_1,\Pi_2). \qquad (11)$$

Corollary 2.

The final most productivity network indicator for Artificial Intelligence mechanism calculations is the limit of the sum of output impulse mechanisms having the least sum of connections.

7. Conclusions

Logical network analysis in graphical form as a mathematical implementation for intelligent micro-bearing numerical calculations is presented in this paper. Presented paper establish the scheme of calculation algorithm of hydrodynamic pressure and carrying capacity changes in micro-bearings for various journal shapes and for various geometries.

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