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LOGICAL NETWORK OF VECTOR SPACES FOR INTELLIGENT OPTIMUM VALUES OF OPERATIONAL SLIDE BEARING PARAMETERS

SIECI LOGICZNE PRZESTRZENI WEKTOROWYCH DLA INTELIGENTNYCH OPTYMALNYCH WARTOŚCI PARAMETRÓW EKSPLOATACYJNYCH ŁOŻYSK ŚLIZGOWYCH

Key words:

micro-bearings, robots, memory of carrying capacity, artificial intelligence, logic

Słowa kluczowe:

mikro-łożyska, roboty, pamięć, nośność, sztuczna inteligencja, logika

Summary

This paper presents the implementation of logical network of vector spaces in topological form as a artificial intelligence component applied for determination of optimum system design regard to the micro-bearing operating

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parameters such as carrying load capacity, friction forces, friction coefficient and bearing wear. The tools of fuzzy logic, and robotics development calculations are applied. Presented in this paper artificial intelligence tools of calculations for micro-bearings systems determine the method using in mechatronics where are investigated the principles of intelligent behavior of micro-bearings and are created its new formal models using computer programs which can make simulations models of slide micro-bearing behavior during the exploitation process.

Fuzzy logic is a mathematical object with defined multivalued function which has values in closed set [0,1]. In classical case mentioned function has only two values namely zero and one. This paper presents the fuzzy logic tools in intelligent micro-bearing systems.

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.

LOGICAL NETWORK OF Vector IMPULSES FOR BEARING SYSTEM

Artificial intelligence supported by the logical network of impulse vector space is included in the industry of new technologies and in many of the most difficult problems connected with data optimisation during computer program performances [**L. 1**, **2**]. Network analysis for Artificial Intelligence (AI) research is highly applied mathematical knowledge. Subfields of Logical Network of Vector Spaces (LNVS) in the field of slide journal bearing systems are organised around the following particular problems:

- The identification of micro-bearing design models of LNVS as the objective of a control system [**L. 6**].
- The study of the simplification of the Logical Network Analysis Scheme (LNVS) by virtue of graphical topology and an attempt to create an equivalence of Logical Network Vector Space $(LNVS)_{eq}$ using the logical set theory and topology laws [**L. 3–5**] and,
- The applications of logical network analysis to the intelligent control theory and cyber-bio-tribology.

IDENTIFICATION OF BEARING DESIGN

Logical Network Analysis Scheme (LNVS) is part of the Artificial Intelligence (AI) of micro-bearing systems. LNVS begins with electronic input impulses U and finishes with output electronic impulses Y. **Fig. 1** presentes the control system during micro-bearing design:

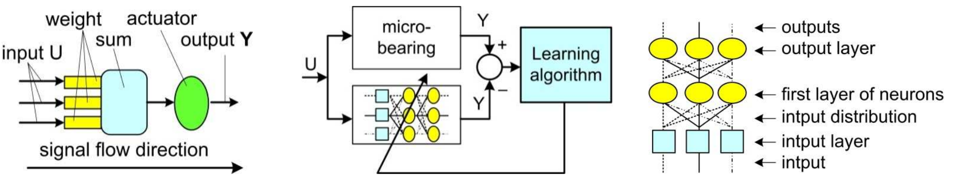

Fig. 1. Control system: a) signal flow, b) bearing design identification, c) two layer neural network

Rys. 1. System sterowania: a) przepływ sygnału, b) identyfikacja projektowania, c) warstwy sieci neuronów

In slide journal bearing systems we have the input vector **U**(A, B, C, D,…) in multi-dimensional space. The components of this vector have various meanings. For example, the electronic impulse vector Y denotes the anticipated optimum bearing if we take into account the following: A – the shape of the micro-bearing journal, B – bearing solid material, C – kind of lubricant, D – roughness of bearing surface; E_n – various operating parameters of micro-bearing (load carrying capacity, friction forces, wear,…) for n = 1, 2,…; F_n – various external conditions for n = 1, 2,… (operating temperature, magnetic field,…). The electronic impulse vector **Y** denotes anticipated optimum bearing.

THE LOGICAL TOOLS

Let us now consider the tools of LNVS occurring in micro-bearing electronic network and in computer science [**L. 5**]. We assume the following nods as connection boxes:

$\cup$ – union (sum) mechanism,

$\cap$ – intersection mechanism which choices common properties of two impulses,

~ – mechanism which negates each impulse.

The above mechanisms are presented and explained in **Fig. 2.**

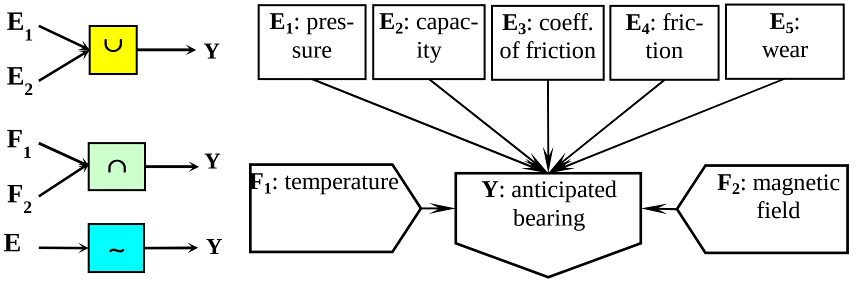

Fig. 2. Input impulse E and F going into nods and output impulse Y outgoing from the nods
Rys. 2. Impulsy wejścia E oraz F wchodzące do węzła oraz impuls wyjścia Y

CONTROL STRATEGIES FOR TWO EQUIVALENT SPACES

Now for one device, we can assume the following expression:

$$Y_1(A,B,C,D) =[\sim(A\cup C)\cap B]\cup\{[(\sim C\cap B) \cup D] \cap A\}, \tag{1}$$

where: A, B, C, D – input impulses, Y(A, B, C, D) – output impulse of first kind.

In practical cases we have a lot input impulses. The tribo-topology scheme of $(LNAS)_1$ for the formula (1) is presented graphically in **Fig. 3**.

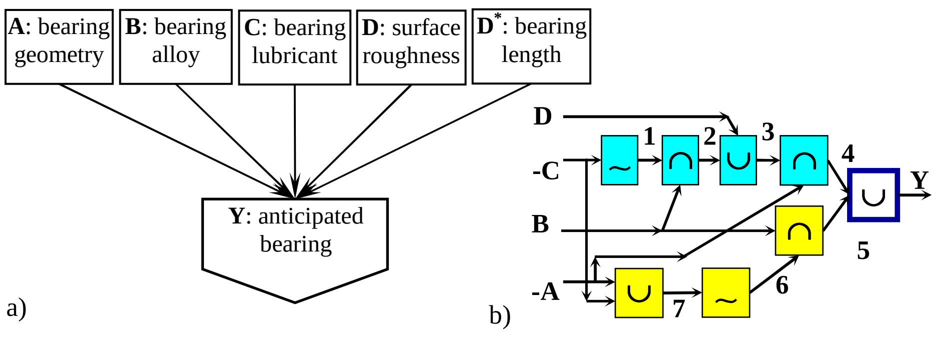

Fig. 3. Example a) and Logical network scheme b) for Y_1 =$(LNAS)_1$ for seven connections
Rys. 3. Przykład a) oraz schemat sieci logicznej b) dla Y_1 = $(LNAS)_1$ z siedmioma połączeniami

By virtue of the set theory the expression (1) can transform as follows [**L. 5**]:

$$\begin{aligned} Y_1 &\equiv[\sim(A\cup C)\cap B]\cup\{[(\sim C\cap B) \cup D] \cap A\}= \\ &=[\sim A\cap(\sim C\cap B)]\cup\{[(\sim C\cap B) \cap A]\cup(A\cap D) \}= \\ &=[\sim A\cap(\sim C\cap B)]\cup[(\sim C\cap B) \cap A]\cup(A\cap D) =(\sim A\cup A)\cap(\sim C\cap B)\cup(A\cap D) = \\ &=X\cap(\sim C\cap B)\cup(A\cap D) \equiv(\sim C\cap B)\cup(A\cap D) \equiv Y_{1eq}. \end{aligned} \tag{2}$$

Symbol Y_{1eq} denotes total space of impulses. **Fig. 4** graphically presents the output impulse Y_{1eq} treated as a result of (3) for A,B,C,D – input impulses. It is evident that, in this case, the equivalent scheme Y_{1eq} presented in **Fig. 4** is simpler than the origin scheme Y_1 presented in **Fig. 3** because for example Y_1 has seven connections between two variable nods (boxes), and Y_{1eq} has only three. In this case, the number of connections and the network of transmission impulses can be more appropriate and more productive.

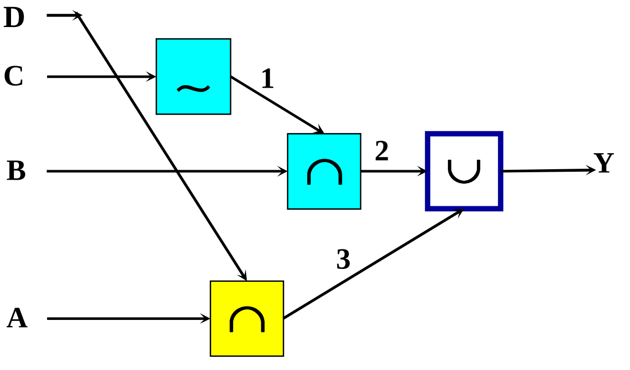

Fig. 4. Tribo-topology logical network analysis scheme $(LNVS)_{1eq}$: $Y_{1eq} \equiv (\sim C \cap B) \cup (A \cap D)$ for three connections

Rys. 4. Sieć logiczna $(LNVS)_{1eq}$: $Y_{1eq} \equiv (\sim C \cap B) \cup (A \cap D)$ z trzema połączeniami

We can now consider the presented input electronic impulses method of the second type. We take into account the next output impulse:

$$Y_2(E_1,E_2,F_1,F_2) \equiv [\sim(E_1 \cap E_2) \cup F_1] \cap [\sim (F_1 \cup \sim F_2) \cap E_1] \tag{3}$$

where: E_1, E_2, F_1, F_2 – input electronic impulses, Y_2 – output impulse. On the basis of simple set theory we can transform thisexpression (3) into the following form:

$$\begin{aligned} Y_2 &= [\sim(E_1 \cap E_2) \cup F_1] \cap [\sim (F_1 \cup \sim F_2) \cap E_1] = \\ &= (\sim E_1 \cup \sim E_2 \cup F_1) \cap (\sim F_1 \cap F_2 \cap E_1) \equiv Y_{2eq}. \end{aligned} \tag{4}$$

A new tribo-topological scheme of network Y_2 described by Formula (3) and Y_{2eq} described by Formula (4) are presented in **Fig. 5**.

Clearly, in this case the scheme Y_1 of the origin network presented in **Fig. 5a** and the equivalent scheme Y_{2eq} presented in **Fig. 5b** have the same number of connections.

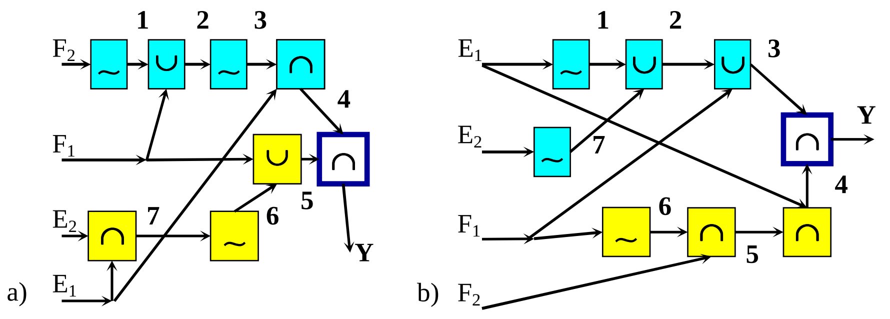

Fig. 5. Logical network: a) Y_2 after (3) and b) Y_{2eq} after (4), both with seven connections
Fig. 5. Schemat logiczny: a) Y_2 według (3) oraz b) Y_{2eq} w/g (4), oba z siedmioma połączeniami

The arrow denotes the direction of impulse transmission. The goal is to find such Y_{2eq} that satisfies the following expression [**L. 3**, **5**]:

$$\left\| Y(A,B,C,D,E,F) - Y_{eq}(A,B,C,D,E,F) \right\| \leq \varepsilon \tag{5}$$

where $\| \ \|$ denotes the norm of function Y that can be found by special input-output pairs. Symbol ε should be selected in such a range that guarantees the necessary accuracy.

The final calculation indicator Y_F is defined as a union of three elements namely of the two best output impulses of two kinds of networks Y_{1eq}, Y_{2eq} including various transmission impulses and the best kind Y_{ceq} of partial modified differential calculation method describing pressure and load carrying capacity distribution. This indicator is defined in the following form [**L. 6**]:

$$Y_F = Y_{1eq}(A,B,C,D) \cup Y_{2eq}(E_1,E_2,F_1,F_2) \cup Y_{ceq}. \tag{6}$$

NUMERICAL TOOLS

Fig. 7 presents pressure distribution and load carrying capacity in a cylindrical slide micro-bearing as a one component of the output vector by virtue of the numerical calculations [**L. 5**] using a modified Reynolds equation performed in Matlab 7.4 Professional Program. The final calculation indicator with the sum of output impulses having the least sum of connections is a most productive logical network of data transmission impulses in journal bearing design.

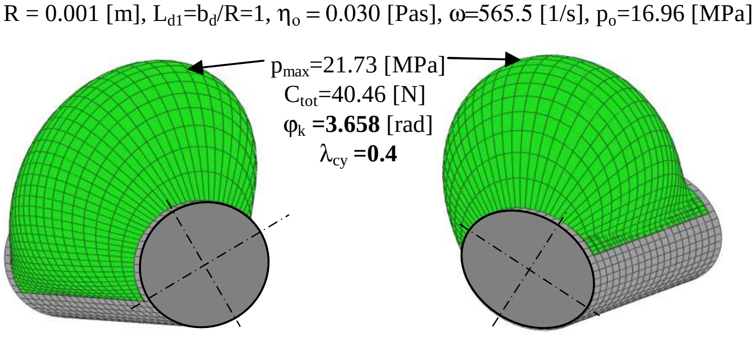

Fig. 7. The pressure distributions in radial micro-bearings by the rotation in circumferential direction
Rys. 7. Rozkład ciśnienia w walcowym mikrołożysku wywołany ruchem obrotowym

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 set theory implementation constitute a new convenient tools of artificial intelligence methods and computer calculation methods occurring in numerous applications [**L. 4**]. This work has established a scheme for the calculation of the algorithm of hydrodynamic pressure and carrying capacity changes in journal-bearings for various journal shapes and for various geometries. The above mentioned results enable one to investigate the dynamic behaviour of a journal bearing system by solving modified a Reynolds equation and the equations of motion in some degree of freedom. It shows that the dynamics of a journal bearing can be affected not only by the design variables but also by existing motor parameters [**L. 3**, **5**, **6**].

Streszczenie

Rozpatrywane w niniejszej pracy badania naukowe opisują topologiczną analizę najprostszych sieci logicznych dla konstruowania przestrzeni wektorowych o składowych opisujących inteligentne optymalne wartości parametrów eksploatacyjnych takich, jak ciśnienie, temperatura, siły tarcia, składowe prędkości cieczy smarującej i inne, które są rozwiązaniami opisanych równań różniczkowych cząstkowych. Przedstawiony system wiodący od założeń do rozwiązań pozwoli na ukonstytuowanie się najkorzystniejszego procesu sterowania poszukiwanymi parametrami eksploatacyjnymi, przy wykorzystaniu optymalnych sieci logicznych w trakcie projektowania łożysk ślizgowych.

Omawiane systemy topologiczne wiodą do tworzenia optymalnych algorytmów obliczeń numerycznych wartości ciśnienia hydrodynamicznego i siły nośnej łożysk ślizgowych dla różnych kształtów geometrycznych czopów i panewek w rozpatrywanych łożyskach ślizgowych. Przedstawione rezultaty badawcze umożliwiają badanie i optymalizowanie sztywności hydrodynamicznej oraz parametrów dynamicznych łożysk ślizgowych w trakcie projektowania. Uzyskane quasi-logiczne rozwiązanie problemu hydrodynamicznego, opisanego układem równań różniczkowych w obszarach cieczy i ciała stałego, wpływa na ich dokładność w porównaniu z dotychczas stosowanymi rozwiązaniami.

W przypadku trafnie dobranych warunków brzegowych dla rozwiązywanych układów równań oraz prawidłowo zbudowanych stanowisk badawczych, a także dokładnych odczytów w mikroskopach sił atomowych i innej wykorzystywanej aparatury i sprzętu, dochodzimy do coraz lepszego korygowania różnic pomiędzy wynikami analityczno-numerycznymi i wynikami uzyskanymi na drodze eksperymentu. Niniejsza praca przedstawia pewne wdrożenie analizy sieciowej w logiczno-topologicznej postaci komponentu sztucznej inteligencji, zastosowanego do określenia optymalnego systemu projektowania, dotyczącego parametrów eksploatacyjnych łożysk takich, jak nośność, siły tarcia, współczynnik tarcia, zużycie łożyska.

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