Simulation, Modelling and Optimization for Operative Maintenance

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Abstract: - The paper proposes the achievement of a predictive maintenance conception for the operative maintenance through the prediction of the wear degree of the cryogenics dynamical systems having as variable the monitoring of the lubrication from oiling system of the components with dynamical function.
The monitoring wear degrees knowing at a given moment of the dynamical components is determined through the fuzzy method the wear degree of the system formed from monitoring components.

Key-Words: - Maintenance Simulation, Maintenance Optimization, Predictive maintenance, LabVIEW.

1 Introduction

The fuzzy logic, one from the command and adjustment modern methods of the systems, is applied at present in the management of installations and the automation of diverse equipments by reason of main possibilities to enter simple the different types of conditions more or less mathematical.
One what in come next is proposed a mode of introduction of the fuzzy systems in the management of the predictive maintenance based on the monitoring of the wear degree at the dynamic equipments.
The conception for the predictive technique used in this paper supposes the systematic accumulation of data came from the lubrication monitoring, the establishment of an evolution tendencies of these values in time and the fixing of an intervention levels for the correction of the probable damages. The data quantity is advisable to be big enough to substantiate a decision.
The lubricant who circulates through equipment is a bearer of information concerning the wear stage of the components from the oil circuit. The lubricant monitoring follows the analysis of particles in suspension and those deposited. Usually the particles over 10 microns remain in suspension and those by 40 microns are deposited. The particles in suspension are restrained by filters and by magnetic elements placed in fluid flux or in fixed parts of the equipment. These mechanical collectors have varied constructions.
The quantities of suspension that pass through filter provoke a pressure decrease which constitutes the followed parameter.
The detection of metallic or non-metallic particles is realized through the utilization of a special sensor whose function principle is based on the erosion by the particles in suspension of a metallic film; his electrical resistance is modified, establishing a connection between this and the characteristics of particles in suspension (dimension, concentration).
The tribological analyses evaluate the possible damages through the analysis of all lubricant constituents and the comparison with the lubricant parameters before put into operation of the equipment.

2 Problem Formulation

The problem which it is put is the mathematical modeling for the taking of the decision of optimum time of operative maintenance, respectively the realization simulation depending of the evolution of wear degree for dynamic components utilizing software LabVIEW produced of National Instrument.

2.1 Modelling conception for simulation

The conception objective is constituted by application of fuzzy method as viable solution for the taking of the decision for an activity of applied operative maintenance for example the dynamic equipments from nuclear installations where the maintenance is fundamental. There where the maintenance is fundamental is justified a monitoring activity of the wear degree of equipments as part of the predictive maintenance.
For the taking of the decision is utilized the fuzzy method that involve in generally three operations:

- Fuzzyfication: Translation from real world values to Fuzzy values.
- Rule evaluation: Computing rule strengths based on rules and inputs
- Defuzzyfication: Translate results back to the real world values

For the wear degree of the elements x, y (given by the parameter followed the fall of pressure in filters, respectively the dimensional evaluation of metallic particles and non-metallic from lubricant) is considered only the temporal dependence of the parameter which expresses the wear of the marks. Others factors as the conditions of environment, the size of the solicitations are considered that influence default the values of the wear.

So considering given a system s=s(x,y) will be determined the wear degree u(s), knowing the wear degrees u(x) and u(y), that is:

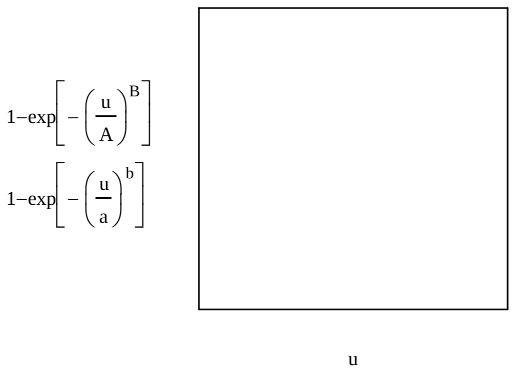
u(s) =u(u(x),u(y)) *(1)*

2.1.1 Fuzzyfication

The input variables are considered the wear degrees of the components, respective u(x) and u(y) and as output variables, the wear degree of the system u(s).

In the fuzzyfication process have been chosen membership function simple, by triangular or trapezoidal type. On measure of the increase of the knowledge volume specify of the tribological monitoring domain will be introduced more complicated functions but that are more adequate to the phenomena.

The wear degree as independent measure can't be fuzzyfication. In consequence is started from a form of dependence between the pressure through filters and wear of the marks. This dependence on basis of the



u := 0.0, 0.1.. 5 B := 1

b := 2 a := 2 A := 2

Figure 1. Real world value for wear degree u(x) and u(y)

experience can be associated of a Weibull function in expression of the failure probability as a result of the wear degree for the components x and y as in Fig. 1.

Translation from real world values to Fuzzy values makes using membership functions. The membership function in Fig.2, translate a wear degree 0.7 from Fig.1 equal 7 microns into fuzzy values (Degree of membership) low=0.1595, medium=0.3333, high=0.

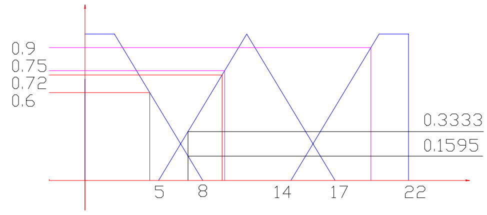


Figure 2. Translation from real world values to Fuzzy value

The symbols of fuzzy crowd defined on existence domains of the variables and the linguistic qualitatives attributed them are found in table 1.

Table 1

U(x)		U(y)		U(s)	
$\tilde{m}_x$	LOW	$\tilde{m}_y$	LOW	$\tilde{m}_s$	LOW
$\tilde{Me}_x$	MEDIUM	$\tilde{Me}_y$	MEDIUM	$\tilde{Me}_s$	MEDIUM
$\tilde{M}_x$	HIGH	$\tilde{M}_y$	HIGH	$\tilde{M}_s$	HIGH

The fuzzy crowds from table 1 are defined by terms (2)…(11).

$$\tilde{m}_x = \{(u(x), \mu_{\tilde{m}_x}(u(x))) | u(x) \in [0,8.0]\} \quad (2)$$
$$\tilde{Me}_x = \{(u(x), \mu_{\tilde{Me}_x}(u(x))) | u(x) \in [5,17]\} \quad (3)$$
$$\tilde{M}_x = \{(u(x), \mu_{\tilde{M}_x}(u(x))) | u(x) \in [14,22]\} \quad (4)$$
$$\tilde{m}_y = \{(u(y), \mu_{\tilde{m}_y}(u(y))) | u(y) \in [0,8.0]\} \quad (5)$$
$$\tilde{Me}_y = \{(u(y), \mu_{\tilde{Me}_y}(u(y))) | u(y) \in [5,17]\} \quad (6)$$
$$\tilde{M}_y = \{(u(y), \mu_{\tilde{M}_y}(u(y))) | u(y) \in [14,22]\} \quad (7)$$
$$\tilde{m}_s = \{(u(s), \mu_{\tilde{m}_s}(u(s))) | u(s) \in [0,20]\} \quad (8)$$
$$\tilde{Me}_s = \{(u(s), \mu_{\tilde{Me}_s}(u(s))) | u(s) \in [10,30]\} \quad (9)$$
$$\tilde{M}_s = \{(u(s), \mu_{\tilde{M}_s}(u(s))) | u(s) \in [20,40]\} \quad (10)$$
$$0 < u_{z,i} < u_{z,j}; i < j, z \in \{x, y, s\}$$

2.1.2 Rule evaluation

It is establishment stage of the relation between components and system, resulting Fuzzy Rules Base (FRB).

Table2

Regula	u(x)	u(y)	u(s)
R1	$\tilde{m}_x$	$\tilde{m}_y$	$\tilde{m}_s$
R2	$\tilde{m}_x$	$\tilde{Me}_y$	$\tilde{m}_s$
R3	$\tilde{m}_x$	$\tilde{M}_y$	$\tilde{Me}_s$
R4	$\tilde{Me}_x$	$\tilde{m}_y$	$\tilde{Me}_s$
R5	$\tilde{Me}_x$	$\tilde{Me}_y$	$\tilde{Me}_s$
R6	$\tilde{Me}_x$	$\tilde{M}_y$	$\tilde{Me}_s$
R7	$\tilde{M}_x$	$\tilde{m}_y$	$\tilde{Me}_s$
R8	$\tilde{M}_x$	$\tilde{Me}_y$	$\tilde{M}_s$
R9	$\tilde{M}_x$	$\tilde{M}_y$	$\tilde{M}_s$

The fuzzy rules establishment are made through heuristic methods. Will result a number of rules equal 3x3=9, going from the number of fuzzy sets associated each input variable (see table 1),. These rules can be from table 2.

For each fuzzy rules established in paragraph b) is established membership degree of the variable output u(s) to fuzzy set respective, used operator MIN.

for R1: $\mu_{\tilde{m}_{s,1}} = MIN\left[\mu_{\tilde{m}_x}(u(x)), \mu_{\tilde{m}_y}(u(y))\right]$ (12)

for R2: $\mu_{\tilde{m}_{s,2}} = MIN\left[\mu_{\tilde{m}_x}(u(x)), \mu_{\tilde{Me}_y}(u(y))\right]$ (13)

for R3: $\mu_{\tilde{Me}_{s,3}} = MIN\left[\mu_{\tilde{m}_x}(u(x)), \mu_{\tilde{M}_y}(u(y))\right]$ (14)

for R4: $\mu_{\tilde{Me}_{s,4}} = MIN\left[\mu_{\tilde{Me}_x}(u(x)), \mu_{\tilde{m}_y}(u(y))\right]$ (15)

for R5: $\mu_{\tilde{Me}_{s,5}} = MIN\left[\mu_{\tilde{Me}_x}(u(x)), \mu_{\tilde{Me}_y}(u(y))\right]$ (16)

for R6: $\mu_{\tilde{Me}_{s,6}} = MIN\left[\mu_{\tilde{Me}_x}(u(x)), \mu_{\tilde{M}_y}(u(y))\right]$ (17)

for R7: $\mu_{\tilde{Me}_{s,7}} = MIN\left[\mu_{\tilde{M}_x}(u(x)), \mu_{\tilde{m}_y}(u(y))\right]$ (18)

for R8: $\mu_{\tilde{M}_{s,8}} = MIN\left[\mu_{\tilde{M}_x}(u(x)), \mu_{\tilde{Me}_y}(u(y))\right]$ (19)

for R9: $\mu_{\tilde{M}_{s,9}} = MIN\left[\mu_{\tilde{M}_x}(u(x)), \mu_{\tilde{M}_y}(u(y))\right]$ (20)

It is observed that membership of the wear degree to a fuzzy set can derive from one or many fuzzy rules, so that result different membership degree at a same fuzzy set. It is need of a single membership degree and for determined it, is applied operator MAX, corresponding the reunions of fuzzy sets. It results:

$$\mu_{\tilde{m}_s} = MAX\left[\mu_{\tilde{m}_{s,1}}; \mu_{\tilde{m}_{s,2}}\right]; \quad (21)$$

$$\mu_{\tilde{Me}_s} = MAX\left[\mu_{\tilde{Me}_{s,3}}; \mu_{\tilde{Me}_{s,4}}; \mu_{\tilde{Me}_{s,5}}; \mu_{\tilde{Me}_{s,6}}; \mu_{\tilde{Me}_{s,7}}\right]; \quad (22)$$

$$\mu_{\tilde{M}_s} = MAX\left[\mu_{\tilde{M}_{s,8}}; \mu_{\tilde{M}_{s,9}}\right] \quad (23)$$

You may have a rule like this: If Ux=LOW and Uy=MEDIUM then Us= MEDIUM. Suppose (see Fig.2) LOW=0.6 and MEDIUM=0.72. The rule strength will be 0.6 (The minimum value of the antecedents) and the fuzzy variable MEDIUM would be also 0.6.

Consider now another rule: If Ux=MEDIUM and Uy=HIGH then Us=MEDIUM. Let be in this case (see Fig.2), MEDIUM=0.75 and HIGH=0.9 and the fuzzy variable MEDIUM would be also 0.75.

So, we have two rules involving fuzzy variable MEDIUM. The "Fuzzy OR" of the two rules will be 0.75 (The maximum value between the two proposed values). MEDIUM=0.75.

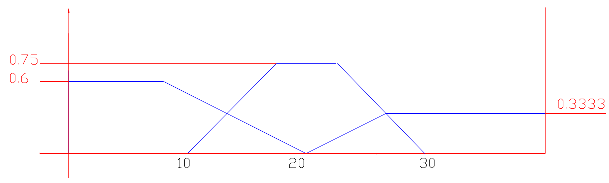


Figure 3.

2.1.3 Defuzzyfication

After we compute the fuzzy rules and evaluate the fuzzy variables, we will need to translate these results back to the real world. We need now a membership function for each output variable like in Fig. 3.

Let the fuzzy variables for u(s) be: LOW=0.6;

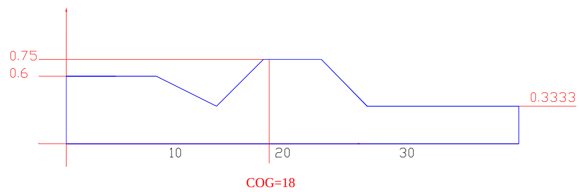


Figure 4.

MEDIUM=0.75; HIGH=0.33.

Each membership function will be clipped to the value of the correspondent fuzzy variable as shown in Fig. 3.

A new output membership function is built, taking for each point in the horizontal axis, the maximum value between the three membership values. The result is shown in Fig.4

To complete the Defuzzyfication process, all we have to do now is found an equilibrium point. One way to do

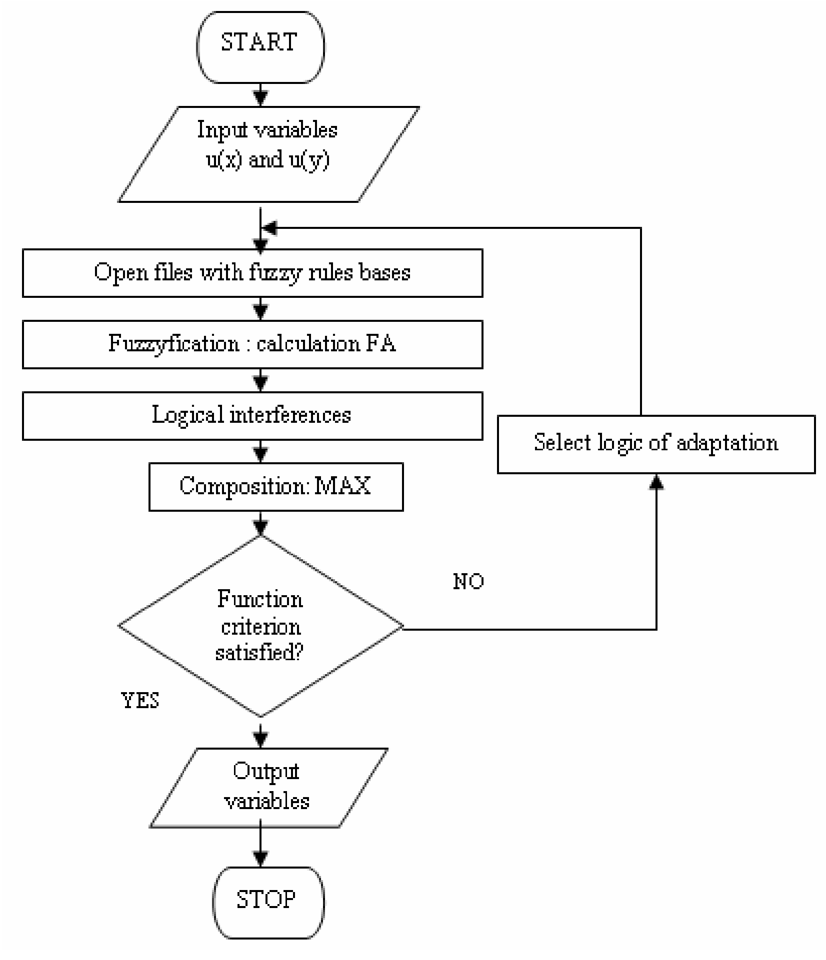


Figure. 5. Method of algoritm

this is with "Centre of Gravity method" (COG).

$$COG = \frac{\int_a^b F(x) \cdot x dx}{\int_a^b F(x)}$$ Which in example COG=1.8 wear degree for u(s).

3. Simulation with LabVIEW

LabVIEW simulation [8] has at basis the algorithm from Figure 5. Adequately in figures (6,7,8) are processed stages used fuzzy method in LabVIEW software.

LabVIEW permit integration with other techniques of simulations for realization of the maintenance predictive programme.

With LabVIEW can be calculated on-line wear degree of monitoring components. Considering the model of the triangular form function are defined domains for fuzzyfication, respective for established and known variables x and y as in figure 6.

LabVIEW permit integration with other technique of simulations for realization of the maintenance predictive programme.

For the case which is exceeded the maximum limit pre-established for wear degree of the monitoring system the simulation is foreseen with visual and auditory alarm system conform figure 6.

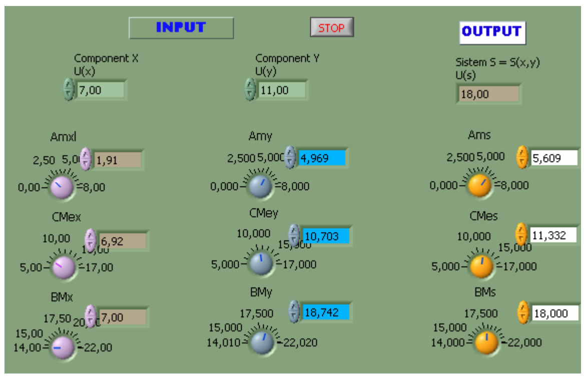


Figure. 6, Maintenance Modelling

Also the simulation permit the calculus and warning of hours number until the next revision of the monitoring system.

Fig.7, Panel LabVIEW for indicate failure with urgent intervention of operative maintenance.

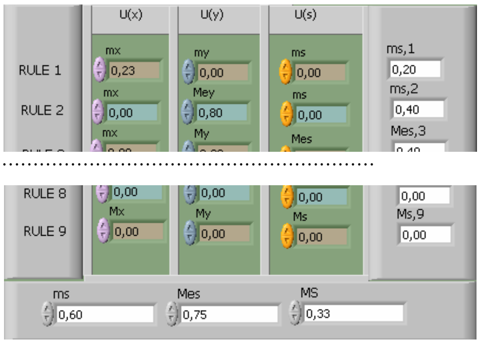


Fig.8, The Rule with LabVIEW software

4 Conclusion

The knowing and the evaluation of the system components for wear degree constitute an important variable among many other variables used for realization of an advanced Operative Maintenance Program for Nuclear Plant.

The conception of method permits the realization in dynamic regime an operative predictive program on-line.

References:

[1] Bogdan O.,I, *Utilizarea multimilor fuzzy in fiabilitate*, Editura ATU, Sibiu, 2000

[2] Byron Miller – *A Case For Fuzzy Logic*, EMBEDDED SYSTEMS PROGRAMMING, December 1995, 42:70.

[3] Jayabalan, V., Chaudhuri, D., *Cost Optimization of Maintenance Scheduling for a System with Assured Reliability*, IEEE Transactions on Reliability,

[4] J.A. Morman, J. Reifman, J. E. Vitela, T. Y. C. Wei, C. A. Applequist, P. Hippley, W. Kuk and L. H. Tsoukalas, *IGENPRO Knowledge-Based Digital System for Process Transient Diagnostics and Management*, Proceeding of the IAEA Meeting on Advanced Technologies for Improving Availability and Reliability of Current and Future Water Cooled Nuclear ower Plants, Argonne, IL, September 8-11, 213-224, 1997.

[5] J. Reifman, Thomas Y. C. Wei, "PRODIAG: *A Process-independent Transient Diagnostic System-I: Theoretical Concepts*, Nuclear Science and Engineering, 131, 1-19, 1999.

[6] Jin Chai and L. H. Tsoukalas, *An Investigation of Fuzzy Trend Algorithms for Nuclear Engineering*, Final Report, 1998.

[7] Kevin Self – *Designning With Fuzzy Logic*, IEE SPECTRUM, November 1990, 42:44, 105.

[8] National Instruments, *LabVIEW – User manual* www.ni.com/pdf/manuals/320999b.pdf.