ESTIMATION OF OPERATIONAL POTENTIAL CONSUMPTION ON BASE OF EXPLOITATION PARAMETERS VALUES

Michał Pająk

Radom University of Technology, Faculty of Mechanical Engineering, Department of Thermal Technology, 26-600 Radom, ul. Krasickiego 54, Poland
tel.: +48 48 361 71 49, e-mail: michalpajak@tkdami.net

Maciej Woropay

University of Technology and Agriculture in Bydgoszcz, Faculty of Mechanical Engineering, Department of Exploitation, 85-796 Bydgoszcz, ul. Kaliskiego 7, Poland
tel.: +48 52 340 84 95, e-mail: kem@atr.bydgoscz.pl

Abstract

The using processes are carried out on a machine during its exploitation phase. It decreases an operational potential value. Because of this it is necessary to carry out the maintenance processes. When the maintenance processes are executed as an exchange of elements, not exploited operational potential increases the costs of the exploitation process of a machine. In case of real industrial objects there is defined value of availability, which should be kept. Then the highest value of the exploited operational potential assures an implementation of a maintenance strategy according to the machine operational condition. In the paper, the idea of an implementation of the mentioned above strategy is presented. The implementation is based on measured values of the exploitation parameters.

An estimation of an operational potential consumption and a fuzzy estimation of the exploitation potential consumption are an object of the paper. Implementation of the fuzzy logic theory could be good solution of the problems, which can be meet during the estimation process of the operational potential consumption on base of the exploitation parameters course of the machine.

Keywords. fuzzy models of systems, linguistic modelling, fuzzy logic, operational potential, artificial intelligence

1. Course of exploitation potential consumption

The processes of an exploitation phase of a machine could be divided into two groups. Controlled and not controlled ones [1]. From the exploitation potential point of view the using and the maintenance processes are the most significant parts of controlled processes [2]. Using processes decrease operational potential of a machine. It could be consider as moving the operational condition of a machine to the area of increased intensity of damage. To increase the value of operational potential the maintenance processes are carried out. The maintenance processes could be executed in form of modernization, repair or exchange of the elements. The maintenance costs increase the costs of the exploitation phase of the machine. Additionally, the maintenance time decrease the operation time of the machine. For this reason, the main objective of the exploitation strategy is to extend the overhauling period. Decreasing the frequency of the repairs increases the value of the operational potential consumption. It could lead to the damage of a machine. In case of the systems where a failure appearance is connected with health or live hazard a preventive maintenance strategy is implemented. This strategy enables to reach the highest value of the reliability factor of the machine. Unfortunately, the implementation of such strategy is a reason of increasing the value of not used operational potential of exchanged elements what affects stream of losses. Higher losses increase the costs of the exploitation phase of the machine life. The best

exploitation strategy should organize using and maintenance processes to assure the highest value of used operational potential.

The operational potential is unambiguously characterized by values of the features of an object. If the features of the object are interpreted as the state variables they describe condition of the machine. Thus, the operational potential is described by condition of the machine. That's why, implementation of the exploitation strategy according to the condition of the machine assures he highest level of used operational potential. Simultaneously, continuous control of the machine condition decreases the probability of the failure appearance.

Currently, the different diagnostic methods are used to monitor the condition of the machine on the base of its features. Only the real time measurements ensure the proper standard of the exploitation security. So, it is necessary to have the measurement devices installed on the object which could collect values of the machine features on-line. Unfortunately, in many cases there are not on-line diagnostic measurements on real industrial objects. The main reasons of that is high cost of measurement devices and technical problems.

2. Estimation of an operational potential consumption

In most cases of the complex industrial processes, on the object there are measuring instruments which collect on-line the values of exploitation parameters of a machine. These parameters are necessary to drive using processes in an optimal way [3]. The parameters contain information about the exploitation process course, so the estimation process of operational condition of the machine for the chosen moment can be base on them.

The operational potential for a chosen moment could be defined according to formula (1).

$$P_u(S_1) = P_u(S_0) - \Delta P_u(cz_r) - \Delta P_u(cz_z), \tag{1}$$

where: S_0 - initial condition of the machine,
  S_1 - final condition of the machine,
  P_u - operational potential value,
  cz_r - wear factors dependent on machine operation,
  cz_z - wear factors independent from machine operation,
  ΔP_u - change of the operational potential value of the machine.

The operational potential value depends on the initial condition of the machine and course of wear factors. Wear factors can be dependent or independent from the operation of the machine.

The initial condition of the machine depends on the course of production phase and preusing processes. At the end of the production phase an operational condition of the device is defined randomly by manufacturer's quality control. But the influence of preusing processes on operational condition of the machine is not monitored usually. Therefore, the initial operational condition of the machine is determined approximately.

The most of exploitation phase wear factors are included in the exploitation parameters set. Therefore, they are recorded in real time. Unfortunately, in many cases, the accurate model of influence of wear factors on the operational potential consumption is unknown [4].

All elements described above are difficulties of estimation process of the operational potential consumption based on the course of the machine's exploitation parameters.

3. Fuzzy estimation of the exploitation potential consumption

According to the presented theory, the estimation process of the operational potential consumption is based on machine's initial operational condition, the course of wear factors and they influence on considered issue.

How it was proven above, initial condition of machine is determined approximately. Simultaneously, the operation condition of the object is described by the values of the object features. So, if they are expressed in the form of Λ fuzzy sets (2)

$$FS_\Lambda(x) = \begin{cases} 0 & \text{dla } x \le lrs \vee x \ge rrs \\ \dfrac{x - lrs}{lrk - lrs} & \text{dla } lrs < x \le lrk \\ \dfrac{rrs - x}{rrs - lrk} & \text{dla } lrk < x < rrs \end{cases}, \qquad (2)$$

where: $FS_\Lambda(x)$ - member function of Λ fuzzy set,
$\quad lrk$ - the lowest value of the fuzzy set kernel,
$\quad lrs$ - the lowest value of the fuzzy set support,
$\quad rrs$ - the biggest value of the fuzzy set support.

the operation condition of the machine will be result of a relation of multidimensional extensions of two-dimensional fuzzy sets (3).

$$\begin{aligned}
ce(FS_1; X_1 \times X_2 \times \cdots \times X_n) &= \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FS_1}(X_1) \,|\, (X_1, X_2, \cdots, X_n) \\
ce(FS_2; X_1 \times X_2 \times \cdots \times X_n) &= \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FS_2}(X_2) \,|\, (X_1, X_2, \cdots, X_n) \\
&\;\;\vdots \\
ce(FS_n; X_1 \times X_2 \times \cdots \times X_n) &= \int_{X_1 \times X_2 \times \cdots \times X_n} \mu_{FSn}(X_n) \,|\, (X_1, X_2, \cdots, X_n)
\end{aligned}, \qquad (3)$$

where: $ce(FS_i; X_1 \times X_2 \times \cdots \times X_n)$ - n-dimensional extension of the fuzzy set no i.

Thanks to the fuzzy set theory implementation, in the model the approximate character of the of the machine's initial condition description is taken into consideration.

In spite of the real time exploitation parameters recording, the inaccuracy occurs also in this area. This uncertainty is related to the description of a wear factor course. It results from finite accuracy of the measurements, inaccuracy of a recording process to database and poor measurements quality.

      The inaccuracy of a recording process results from its digital character. The values of a continuous course of the wear factors are stored into database once a defined period of time. So, it is possible to retrieve from database only approximate value of chosen parameter for the past time. Moreover, the measured values are disrupted because of the failures of the measuring devices. This is the next reason of exploitation parameters fuzzification.

Inaccuracy of the wear factors values could be modelled by Π and Λ type fuzzy sets depending on the measure characteristic [5].

      To implement the method of operational potential consumption estimation on base of the exploitation parameters course, it is necessary to know the mathematical model of the influence of

the wear factors on the consumption process. If the model is not known, thanks to the on-line exploitation parameters storing process, it is possible to create fuzzy model of the consumption process based on the parameters course. Such solution could be implemented when the mathematical model is not known or it's response time is to long [6]. The basis of the fuzzy model generation process is a learning set consisted of the inputs-output samples [7]. In considered issue the values of the exploitation parameters acts as inputs and the value of the remaining operational potential becomes an output. The amount of the remaining operational potential is the function of the exploitation system features so it could be defined by the measurement of the features values. The fuzzy models generated on base of the input-output samples are quite accurate. For example the value of a mean square error could equal *0.07%* [8].

To sum up we can say that the implementation of the fuzzy logic theory could be good solution to the problems, which can be met during the estimation process of the operational potential consumption on base of the exploitation parameters course of the machine.

4. Conclusions

On the basis of the presented above analysis it is possible to formulate the following conclusions:
- remaining operational potential of exchanged elements increase the value of the stream of losses,
- operational potential is unambiguously characterized by the values of the features of an object,
- exploitation parameters contain the information about exploitation process course, so they can be base of the estimation process of the condition of the machine for the chosen moment,
- implementation of the fuzzy logic theory could be good solution of the problems, which can be meet during the estimation process of the operational potential consumption on base of the exploitation parameters course of the machine.

References

[1] Woropay, M., *Podstawy racjonalnej eksploatacji maszyn,* Wydawnictwo Instytutu Technologii Eksploatacji, Bydgoszcz - Radom , 1996

[2] Hebda, M., Mazur, T., *Podstawy eksploatacji pojazdów samochodowych,* Warszawa, WKŁ 1980

[3] Janiczek, R. S., *Eksploatacja elektrowni parowych*, Warszawa, WNT 1992.

[4] Okranjni, J., Mutwil K., Cieśla M., Warchoł A., *Trwałość elementów urządzeń energetycznych,* Wrocław, OBR GRE Wrocław 2003, VI Konferencja naukowo – techniczna PIRE 2003 Karpacz 26-28. XI. 2003

[5] Pająk, M., Muślewski, Ł., *Rozmyty model oceny jakości działania złożonego systemu eksploatacji*, „Problemy Eksploatacji" 3/2005, ITE, Radom 2005

[6] Pająk, M., Kalotka, J., *Zastosowania logiki rozmytej w praktyce,* Radom, ITE 2002, Prace naukowe Elektryka 2(5)

[7] Herrera, F., Lozano, M., Verdegay, J. L., *A learning process for fuzzy control rules using genetic algorithms,* Technical Report DECSAI-95108, Dept. of Computer Science and A.I., University of Grenada, Spain (February 1995)

[8] Pająk, M., *Optymalizacja harmonogramów remontów bloków energetycznych,* praca doktorska, Politechnika Radomska, Radom, 2004.