METHOD OF FIXING CRITERIA FOR EVALUATION TECHNICAL CONDITION OF AERO-ENGINE BEARING SYSTEMS

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Abstract

The paper presents an effort to introduce statistical inference into evaluation of technical condition of friction pairs in a tribological system [1], particularly to determine threshold values in diagnostic evaluation of the system. Calculations have been made in reference to a piston aeroengine of ASZ-62IR type. Fundamental guidelines have been included to be followed by a specialist while evaluating technical condition of an engineering system under examination carried out with various methods interrelated in their applications [2,3].

Introduction

Reliability of an engineering object is determined with reliability of its individual units and components. One of the basic reasons for reliability decrease are tribological processes (the wear/friction ones). Therefore, evaluation of an engineering object (e.g. an aero-engine) from the point of view of its reliability in friction matchings gains unquestionable importance. Due to incomplete knowledge of wear-and-tear processes that proceed within a complex engineering object time to failure effected by friction processes is considered a random variable. A relation between diagnostic levels (e.g.concentration of an elementary substance in oil) and reliability of the engineering object performance has been assumed.

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This gives grounds for elaborating an impartial criterion of evaluating technical condition and enables our activities to be well-oriented to increase life of the friction pairs. There is a series of possible ways (well-grounded within their ranges) of determining reliability indices for the wear-and-tear processes. However, a guiding rule that the criteria mentioned are to be derived from experimental results is and has to be the main objective of any activity in this field. Such a method seems to be the most suitable one, because it takes the complex nature of wear processes into account.

It is absolutely advisable to introduce a criterion for determining a threshold value of the wear, the task being of vital significance while determining reliability of various devices, machines and systems subjected to tribological processes. This is the way of arriving at diagnostic levels, on the basis of which predictions on periods of correct and reliable performance of the object are possible to give then the grounds to develop an algorithm of maintenance and preventive treatment procedures. One of the methods of technical diagnostics, aimed at evaluation of bearing system condition, consists in measuring concentration of selected chemical elements in wear products found in lubricating oil that covers friction pairs.Tests of this kind are usually performed on engineering objects with closed lubrication systems. Chemical analysis is possible with many and various methods. Each one has its own qualified range of operation and application, e.g. a wide measuring capacity useful in quantitative analysis is characteristic of some of them while the same measuring range applied to qualitative analysis features the other ones. Futhermore, all these methods are applicable to media of various physico-chemical constitution (i.e. viscosity, molecular size, tar products content, etc.).

Description of the method

Mean value found from Eq.(1) has been assumed the estimator of an expected value E/q/. Another assumption is that the random variable C_{Fe} has a normal (Gaussian) distribution N(E/q/,σ) and it corresponds, for the systems under consideration,with physics of the phenomenon [3]. The random variable $\frac{q - E/q/}{\sigma}\sqrt{n-1}$ can be assumed to have t-student distribution of n-1 degrees of freedom (2-4) and an exemplary wear process that proceeds within a tribological system components can be illustrated as show in Fig.1. Tab.1. includes the test and calculation results.

$$\bar{q} = \frac{1}{n}\sum q_i \tag{1}$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_i - \bar{q})^2} \tag{2}$$

$$q_L = \bar{q} - t_{\alpha,n-1}\frac{\sigma}{\sqrt{n-1}} \tag{3}$$

$$q_H = \bar{q} + t_{\alpha,n-1}\frac{\sigma}{\sqrt{n-1}} \tag{4}$$

$$P\{q_1 \le Q \le q_2\} = P\{y_1 \le \frac{Q - E(Q)}{\sigma} \le y_2\} =$$

$$= F(y_2) - F(y_1) \tag{5}$$

Tab.1. A statement of results of diagnostic computations in terms of a selected elementary substance (wear products analysis).

Duty time [h]	n	$t_{\alpha,n-1}$	$\bar{q}$	σ	q_L	q_H	y_1	y_2	P	q_{max}	q_{min}
0÷100	19	2,09	8,3	5,1	5,8	10,8	-0,5	0,5	0,38	18,9	0,5
100÷200	19	2,09	5,2	2,4	4,0	6,4	-0,5	0,5	0,38	8,2	0,0
200÷300	25	2,06	4,7	3,5	3,2	6,2	-0,4	0,4	0,33	14,4	0,0
300÷400	35	2,03	8,3	6,4	6,0	10,5	-0,3	0,3	0,27	19,5	0,0
400÷500	13	2,16	4,6	3,9	2,2	7,0	-0,6	0,6	0,47	11,8	0,0
500÷600	19	2,10	8,1	5,0	1,8	18	-2,0	2,0	0.95	17,7	0,0
600÷700	11	2,26	7,9	5,0	4,0	11,9	0,8	0,8	0,58	14,0	0,0

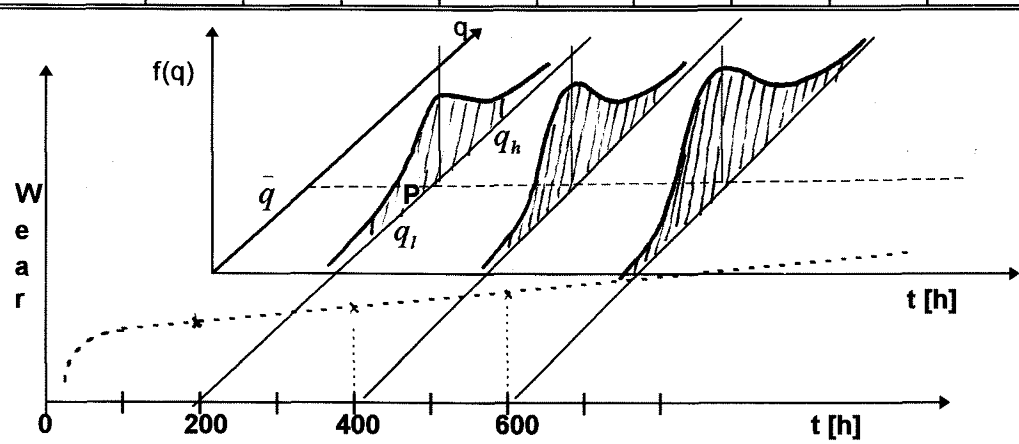

FIGURE 1. An exemplary wear process as a function of duty time, with probability distributions marked.

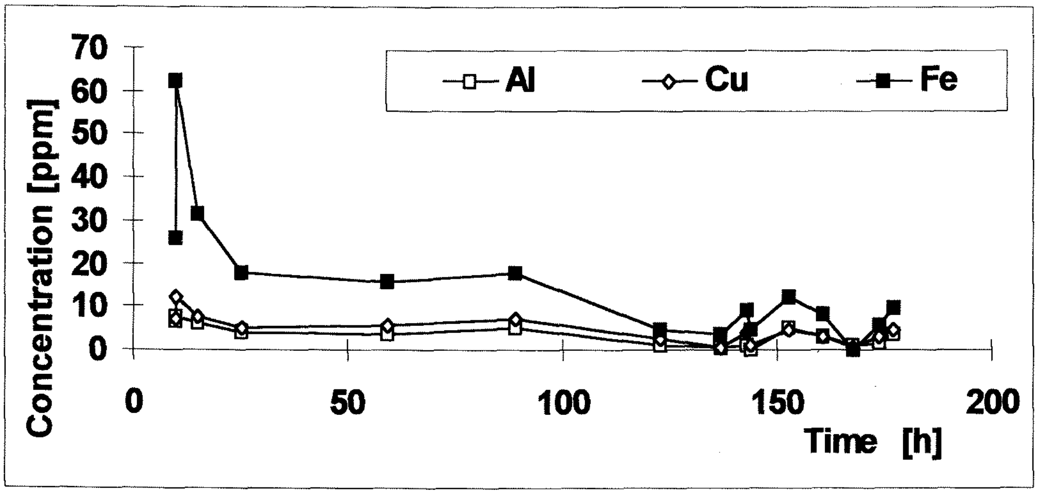

FIGURE 2. Variations in wear product concentrations in aero - engine ASZ-62IR no.4722.

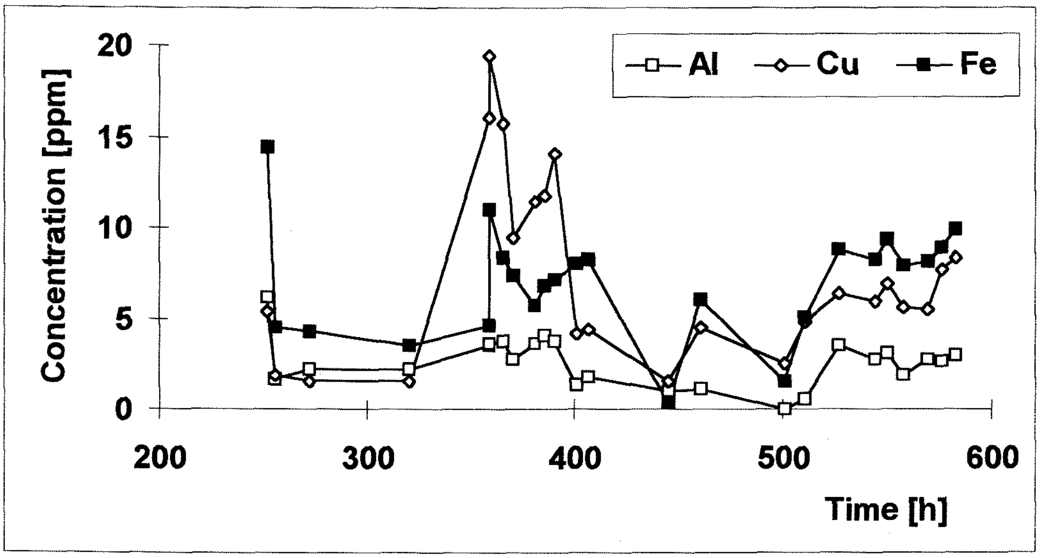

FIGURE 3. Variations in wear product concentrations in aero - engine ASZ-62IR no.7445.

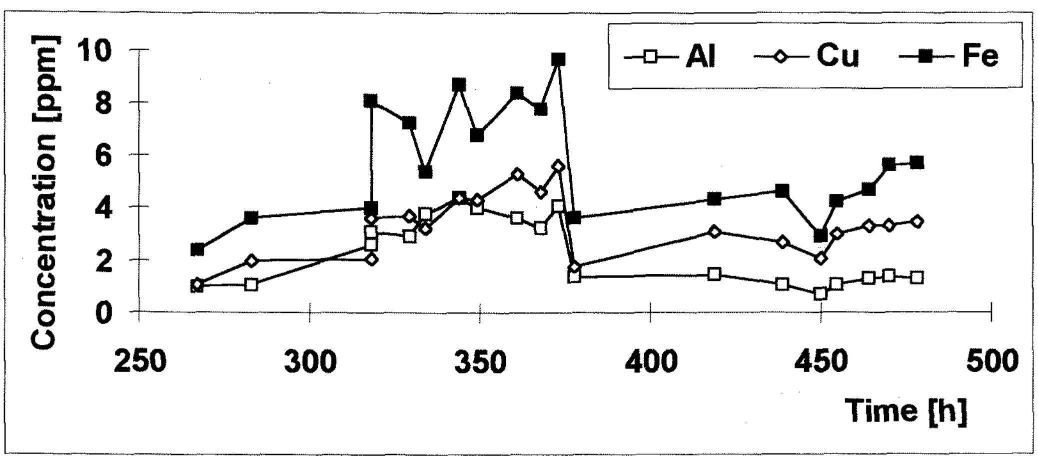

FIGURE 4. Variations in wear product concentrations in aero - engine ASZ-62IR no.5222.

Figs.2-4 show typical variations of wear product concentrations in lubrication systems of aero-engines Asz-62IR. Fig.2 offers a well-rendered running-in period that takes approximately 20 hrs of the engine running time.

Fig.3 represents diagnostic level exceeded for Cu (see Tab.2) and thus recommending the "observed" performance. After approximately 500 hrs increase in Fe concentration evidenced initiation of the final phase of intensive wear that resulted in taking the engine out of service (after 590 hrs). Verification of the tribological system components in terms of their technical condition confirmed that the wear had occurred. Illustrative of the situation observed after approximately 315 hrs of operation is Fig.4. Increased wear of mechanical components of the tribological system was indicated with Al,Cu and Fe concentration growth. Changing the operational conditions of the engine performance resulted in wear product concentration decrease (after 376 hrs), with the tendency to increase, however.

The final phase of the engine operation the so called intensive wear was achieved in a shorter time, i.e. after 450 hrs. The engine was taken out of service as well, after 485 hrs of operation. Quantitative analysis of wear products was carried out using Baird-Atomic Inc. spectrometer of MOA type.

The above described technique of tribological testing work thoroughly confirms suitability of the diagnostic test method applied [5]

Tab.2. Diagnostic matrix as applied to technical condition evaluation

q [ppm]	Al	Ba	Cd	Cr	Cu	Fe	Mg	na	Ni	Si	Sn	Zn
Normal level	2	1	0	1	4	7	1	1	1	1	0	1
Increased level	4	3	1	2	8	12	1	2	1	2	1	4
Intensive level	6	5	1	2	12	17	2	3	1	3	1	6
Failure level	7	6	2	3	17	22	3	5	2	4	2	8

Conclusions

Assuming the wear product concentrations for selected elementary substance be random variables enables wear intensity variations to be followed and recorded for selected time instants of the objects performance. It is of great significance for operational practice, because diagnostic indices (levels) to be applied to technical condition evaluation can be determined by observing wear intensity variations in course of the objects performance time.

Test results make operation of the object according to its technical condition possible.

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