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ESTIMATION OF SYNERGETIC EFFECT IN FACTORIAL – TEMPORAL SPACE FOR ADAPTED INTRODUCED TECHNOLOGIES OF MAINTENANCE SERVICE ON AVIATION TECHNIQUES

Physical essence of the synergetic effect, the mathematical modeling of process of decision-making, the approach to adaptation of techniques for maintenance service on objects of aviation techniques, a task of a qualitative and quantitative estimation synergetic effect, and also a task of an estimation of tendencies in synergetic processes were considered. The algorithm of the decision of tasks in view is resulted.

technical operation and methods of adaptation of techniques for maintenance service, factorial - temporal fields

Introduction

For aircraft operator of aviation techniques (AT) in modern conditions of a choice of various methods of maintenance (MT) it is very important not only to perfect technologies of service suggested directly by the Developer, but also carry advanced, perspective technical decisions of other Developers on its models of AT.

At such approach aircraft operators can receive positive synergetic effect, getting both qualitative technical advantages, and an appreciable financial prize. Synergetic effect is such effect which arises at amplification of joint influence of factors after comparison with the effect received at influence of each them separately refers to process.

1. Formulation of the problem

Now researches of synergetic effect are widely used in the economic analysis of maintenance service on objects AT. However the basic technical component synergetic processes does not occupy due attention till now.

Not in the last turn for this reason, for example, the western technologies of diagnostics of aviation engines (AD) give a positive effect on engines of the Russian manufacture at their application unsufficiently.

In many respects, absence of necessary techniques of adaptation of the developed diagnostic procedures on objects (estimations synergetic effect) AT is the basic obstacle in carry of positive "western" experience, instead of extremely "traditional" opinion about « backlog of element base».

The mathematical model of acceptance of technical decisions should be considered in factorial-temporal space of diagnostic parameters and activities.

It is necessary to note, that mathematically (as well as in reality) synergetic effect can and should be considered both with a sign "+", and with a sign "–", in positive, and negative dynamics.

1.1. Physical interpretation. To evidently illustrate process of monitoring of adaptation of technology MT it is possible using fig. 1.

For presentation we take system of perpendicular planes of two factors $F1$, $F2$ and time T. Let these factors will be $F1$ – relative efficiency of service (for example, quantity found out / the warned refusals with use of a concrete technique to total of refusals) and $F2$ – relative cost of expenses for service of a concrete technique (for example, the financial expenses, falling found out / the warned refusal to the general financial expenses for technical diagnostics / technical operation.

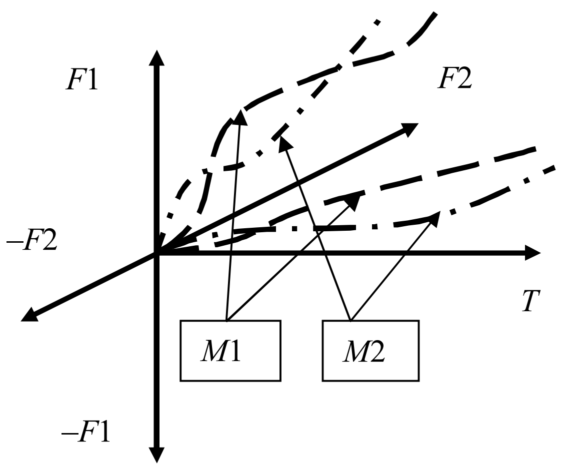

Fig. 1. Monitoring of technology adaptation

Note: By consideration more than two factors it is necessary to representate the process in polar systems of coordinates.

Let there be for a product on the one hand fulfilled technique *M*1 (for example – the statistical analysis), on the other hand there be technique *M*2 (a new equipment, an existing effective technique from the other object, and so on).

There is a requirement of an estimation of new technology from the point of view of its adaptation to existing, estimations of efficiency, a degree of introduction and so on.

The mathematical model of estimations assumes reception of mathematical dependences, an opportunity on this basis of a graphic construction and the comparative analysis of techniques in corresponding factorial-temporal planes.

Thus, besides expert, the complex estimation methods of vector algebra construction of a resulting vector / a line formed by crossing of factorial planes is possible.

Let's consider one of applicable for use in the given statement of a task of a complex estimation and □ffecttive a centroid method of vector algebra [1].

1.2. Geometrical interpretation. Let variables x_1..., x_p are identified with the vectors leaving the beginning of coordinates of *p*-dimensional of space, cosines of corners between vectors are equal to correlations, and lengths of vectors - to standard deviations of corresponding variables.

Further, if directions which are attributed to variables, are already found, we shall change for a while if it is necessary, their marks so that as much as possible correlations became positive; then vectors will tend to a grouping in one direction in a bunch.

After that the first factor 1 (centroid) systems is defined as the sum of vectors and will pass somehow through the middle of a bunch.

Now it is possible to take into account influence of this factor and, having done the further change of marks to come to a new bunch of vectors.

Then it is possible to take into account the second factor (centroid), etc. until the dispersion of variables will not be settled completely.

Generally at us will be **p** vectors in *p*-dimensional space, but essential features of model, it is possible to show, considering only bidirectional case (see fig. 2).

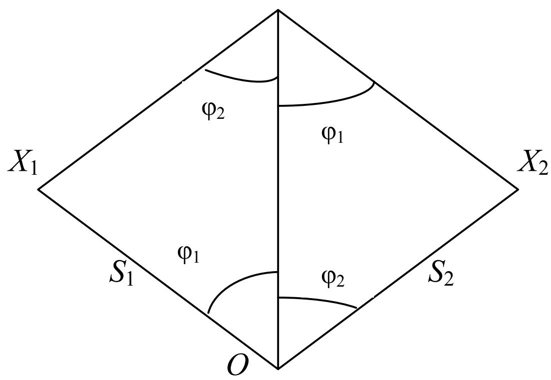

Fig. 2. Bidirectional case of factor vectors

Let X_1 and X_2 – two variables with dispersions S_1^2 and S_2^2 and factor of correlation r. The covariance matrix of them is equal

$$\begin{bmatrix} S_1^2 & rS_1S_2 \\ rS_1S_2 & S_2^2 \end{bmatrix}. \quad (1)$$

Let's present variables x_1, x_2 to vectors OX_1, OX_2 (fig. 2) with a corner Θ between them, where

$$OX_1 = S_1, OX_2 = S_2, \cos\Theta = r. \qquad (2)$$

The sum of vectors OX_1 и OX_2 will be vector OF, where OX_1FX_2 – a parallelogram. This vector after reduction to individual length also represents the first factor $f1$.

Let φ_1 и φ_2 – corners, which are made vector OF with OX_1 and OX_2, so $\varphi_1 + \varphi_2 = \Theta$. Loadings x_1 и x_2 on $f1$:

$$\begin{aligned} l_{11} &= S_1 \cos\varphi_1; \\ l_{21} &= S_2 \cos\varphi_2. \end{aligned} \qquad (3)$$

If a vector of loadings designate through l_1, the residual covariance matrix after the account of influence of the first factor is equal

$$\mathbf{A} - l_1 l_2'$$

or

$$\begin{bmatrix} S_1^2-(S_1\cos\varphi_1)^2 & r S_1S_2-S_1S_2\cos\varphi_1\cos\varphi_2 \\ rS_1S_2-S_1S_2\cos\varphi_1\cos\varphi_2 & S_2^2-(S_2\cos\varphi_2)^2 \end{bmatrix} =$$

$$= \begin{bmatrix} S_1^2\sin^2\varphi_1 & -S_1S_2\sin\varphi_1\sin\varphi_2 \\ -S_1S_2\sin\varphi_1\sin\varphi_2 & S_2^2\sin^2\varphi_2 \end{bmatrix}, \qquad (4)$$

since $r = \cos(\varphi_1 + \varphi_2) = \cos\varphi_1 \cos\varphi_2 - \sin\varphi_1 \sin\varphi_1$. Inasmuch as $S_1\sin\varphi_1 = S_2\sin\varphi_2$, that the sums both in the lines, and on columns this matrix are equal to zero.

Expressing $\cos\varphi_1$ and $\cos\varphi_2$ в (3) through S_1 и S_2 и r, we shall receive a simple method of calculation of loadings of variables on factors directly from covariance matrixes **A**.

For example,

$$l_{11} = S_1\cos\varphi_1 = \frac{S_1^{\,2} + rS_1S_2}{\sqrt{S_1^2 + S_2^2 + 2rS_1S_2}}. \qquad (5)$$

The numerator is equal this expression to the sum of elements of the first column of a matrix **A**, and a denominator to a square root from the sum of all elements of a matrix **A**. Similar expression can be received and for l_{21}.

After that it is necessary to receive loadings of variables on the second factor. They cannot be received directly from a residual matrix as the sums of lines and the sums of columns are equal to zero. Therefore, to promote further, it is necessary to change a mark of one of variables. It is an equivalent to change of a mark in one line and one column of a residual matrix. Then loadings of variables on the second factor turn out summation corresponding columns and a division of each sum into a square root from the sum of all elements of residual covariance matrixes.

In the summary marks of loadings of variables which have been changed, should be restored.

2. Practical application

The above mentioned mathematical device of vector algebra allows quantitatively and to estimate qualitatively various techniques in interdependence crossing (and not crossing) space of every possible integrated parameters and entered individual parameters.

The further step of an estimation of efficiency of techniques probably check of the dependences (vectors) constructed by us on stationary of researched discrete time sequence (time lines) which values is a summing centroid vector / vectors.

Detection of a deviation from stationary is an attribute of presence of a trend and gives the practical recommendation in our case on time of decision-making. The technique of an estimation stationary researched sequence will consist in the following [2].

The algorithm is based on an estimation statistical R – criterion or factor of autoregress establishing event of occurrence of steadily observable deviations the moment of characteristics of time sequence of a diagnostic attribute from initial stationary values unequivocally connected to it.

It is supposed, that the stationary sequence of a diagnostic attribute is described autoregressive by plural model [3]. In vector, a general view this model can be expressed as follows:

$$Y(t+1)-Y(t)\cdot(R-1)+E(t), \qquad (6)$$

where Y – the normalized value of a diagnostic attribute in a time line;

E – vector of random errors (white noise);

$(R - l) - r$ – factor of autoregress (R – criterion of Held).

Condition on which occurrence of non-stationary deviations in sequence of values of a diagnostic attribute is established, i.e. the importance of a trend, is $R < Rkr$. For sequences with the limited lengths of realizations the criterion non-stationary is based on calculation of selective values of factors of autoregress with their subsequent comparison with allowable values.

The choice of length of realization on which is spent statistical estimation, is caused by alternative requirements to sensitivity of algorithm of detection at weak - developing in time a trend and to reliability of his detection with the minimal probabilities of occurrence of mistakes of diagnosing. The small size of the sample is established in case when it is necessary to have a high sensitivity trend at rather satisfactory statistical reliability of result.

Great volumes of the sample are preferable at reception of statistically reliable results of recognition, losing thus in sensitivity.

Practical results show, that the recommended size of the sample of number of members of time realization of a diagnostic attribute makes $N - 10$.

Check on stationary can will be executed consistently by two alternative criteria Held and Cox-Stuart [4].

In the beginning the analysis by criterion Hald which is determined is carried out pays off under the formula:

$$R=\frac{\sum_{l=1}^{m-1}(P_{l+1}-P_l)^2}{2\sum_{l=1}^{m}(P_l-P_a)^2}, \qquad (7)$$

where P – a sample unit; m - the size of sample;

l – a serial number of a sample unit;

P_a – the average arithmetic value designed on sample.

The received value is compared to size Pkr: if $R > Rkr$ sequence of deviations stationary by the given criterion, i.e. the trend is absent. Performance of algorithm on the analyzed parameter stops, the trend is accepted insignificant by the given criterion; otherwise, when $R < Rkr$, it is established presence of a trend with the set confidential probability (for example – 0,95), a trend admits significant by the given criterion and performance of algorithm proceeds.

Further at an establishment of the fact of the importance of a trend by the first criterion each parameter is checked by the second criterion (criteria Held and Cox-Stuart). The criteria Held and Cox-Stuart determines off under the formula:

$$Z=\frac{ABS\left(\left(S-\frac{N}{6}\right)-0{,}5\right)}{\sqrt{\frac{N}{12}}}, \qquad (8)$$

where S – a greater number from quantity of the positive and negative differences received by performance of the following operations: researched sample from N values shares on 3 groups so, that the first and last contain identical number of values M; from the first value of last group the first value of the first group is subtracted, thus the quantity of positive and negative differences is fixed;

ABS – mark of the module.

At the following stage the received value is compared to size Zkp – 2,58:

if $Z < Zkp$, to the sequence is accepted stationary by the given criterion, the trend is absent, the performance of algorithm stops;

otherwise, if $Z > Zkp$ the trend admits significant and by the given criterion, thus performance of the subsequent operations of algorithm proceeds.

In result if the trend is recognized significant by both criteria on sample of values of deviations of parameter factors of linear regress under formulas pay off:

$$b = \frac{\sum_{l=1}^{n}(P_l T_l - mT_a P_a)}{\sum_{l=1}^{m}(T_l^2 - mT_a^2)};$$

$$a = P_a - bT_a, \qquad (9)$$

where P – the sample unit;

P_a – average arithmetic, designed on the sample;

T – the value of an operating time corresponding to a sample unit;

T_a – the average arithmetic value of an operating time designed on the sample of values of an operating time of the system;

l – the serial number of a sample unit;

m – the number of sample units;

b – the factor of a line of regress (speed of a trend);

a – the factor of a line of regress (value of ordinate at abscissa, equal to zero).

The speed of a trend received on the sample is compared with the limiting speed of a trend. At excess of the speed limit the trend of parameter admits SIGNIFICANT. The trend is considered DANGEROUS if for two consecutive events the condition b> b limit satisfies, and the speed of a trend to the in - second sample on the module is more than the speed of a trend in the first sample and the speed of the trend have one mark.

Conclusion

Experience of practical realization of programs of maintenance service of objects AT shows expediency of development of techniques of an estimation of algorithms of adaptation of the perspective development created on related objects. Such approach enables uses of synergetic effect.

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