PRACTICAL ASPECTS OF INDUSTRIAL RELIABILITY ANALYSIS

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Abstract

The different ways of industrial reliability testing and the aims and goals of a product reliability project are outlined. The paper gives the basic theoretical terms on the application of reliability forecasting by pattern recognition method and optimal maintenance control.

Examples on the succesful utilization of the presented methods in industrial practice and further investigation trends are given.

Introduction

The reliability characteristics of industrial products can be determined by calculations or by experimental tests — considering the difficulties of practical applications — using the wellknown basic reliability theory models and methods. (Fig. 1.)

Looking back on a longer time period we had to make a conclusion about the increasing importance of the investigations of field operation in the industrial reliability research.

The main reasons are as follows:

(1) Considering the experimental items, time and costs needed for statistical estimation of reliability characteristics, the laboratory life tests are getting more and more difficult and doubtful. This fact makes the collection and utilization of field operation data unavoidable.

(2) The practical value of a product is to be realized during the operation period, therefore the benefits, the technical-economical characteristics become measurable just in this phase. The reliability research made in different directions and in different periods of design and manufacturing of a product, will result in practical benefits, in measurable technical-economical profit (Fig. 2.).

The above points, furthermore research traditions and the new tendencies determine the aim of our research activity. At the Institute for Precision Mechanics and

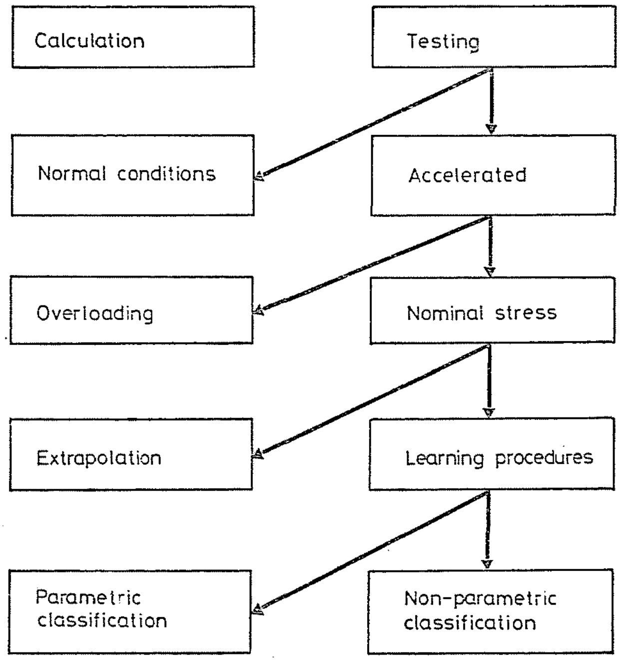
Calculation
Testing
Normal conditions
Accelerated
Overloading
Nominal stress
Extrapolation
Learning procedures
Parametric classification
Non-parametric classification

Fig. 1

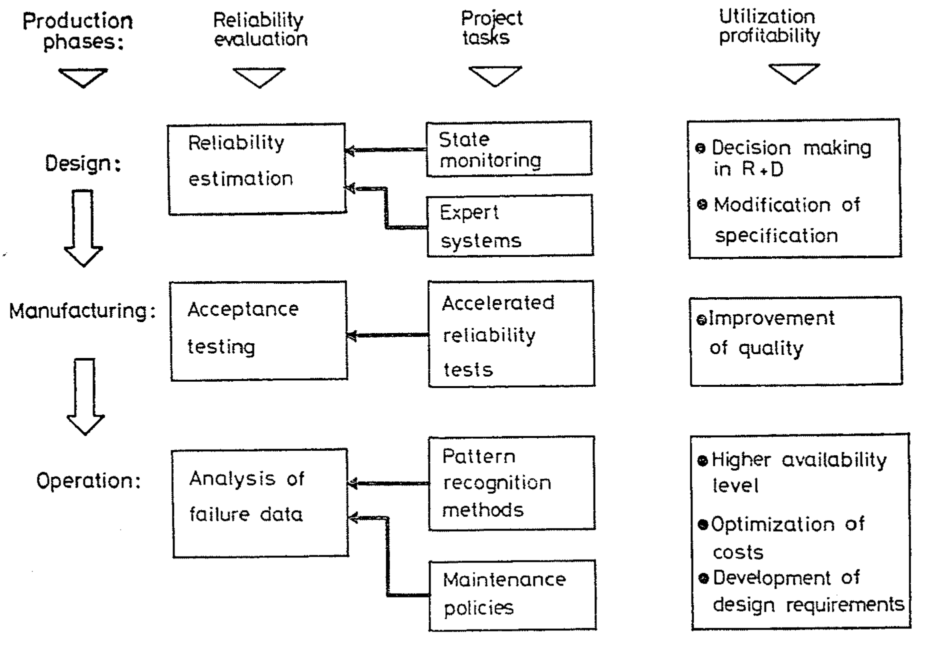
Production phases:
Reliability evaluation
Project tasks
Utilization profitability
Design:
Reliability estimation
State monitoring
Expert systems
Decision making in R+D
Modification of specification
Manufacturing:
Acceptance testing
Accelerated reliability tests
Improvement of quality
Operation:
Analysis of failure data
Pattern recognition methods
Maintenance policies
Higher availability level
Optimization of costs
Development of design requirements

Fig. 2

Optics of the Technical University of Budapest the main research directions of a project considering industrial utilization are as follows:

— State monitoring
— Expert systems
— Accelerated reliability testing
— Application of pattern recognition methods
— Maintenance policies.

Further on we will focusing on the application of pattern recognition methods.

Principle of the application pattern recognition

If the technical state of an equipment at a given time can be described by a set of numbers $\xi_1, \xi_2, \ldots, \xi_n$ where ξ_i is a state characteristic of the equipment, then it can be characterized by a point of an n-dimensional space (state vector).

Forecast of reliability characteristics by pattern recognition methods relies on the comparison of characteristics of the equipment to be tested, and of equipment of a reliability known from previous tests. (1), (2), (3).

The $\bar{\xi}_1, \bar{\xi}_2, \ldots, \bar{\xi}_N$ n-dimensional vectors characterizing all systems of known history, are compiled in an archive. Identical systems will have an identical point, and considering the rate of similarity as distance, the closer two multidimensional spatial points lie, the more similar the corresponding systems are.

In our case the features of similarity may be the different characteristics of reliability, i.e. failure intensity, availability, or degradation.

Let $\bar{x}$ be a realization of the state vector, characterizing the observed equipments, i.e. a point of the learning pattern, and ϱ denotes the corresponding class ("learning"). The aim of the procedure is to find the function

$$f(\bar{x}) = \varrho$$

for the points of the archives $i = 1, \ldots, N$ with a prescribed estimation accuracy for the

$$f(\bar{x}) \sim \varrho$$

Making use of this relationship, for the next observation x_{N+1} the estimation

$$f(\bar{x}_{N+1}) \approx \hat{\varrho}_{N+1}$$

can be given.

The methods of reliability forecasting are based on technical considerations. We assume that from the $\xi_1, \xi_2, \ldots, \xi_n$ state parameters enough information can be obtained for the estimation of the class ϱ. The most appropriate state parameters characterizing the damaging or the failure processes may be selected on the basis of technical experiences. The major steps of solution of pattern recognition problems are as follows:

(1) Choice of parameters $\xi_1, \xi_2, \ldots, \xi_n$ corresponding to the observation of state. (Feature extraction)

(2) Estimation of the function $f(\bar{x}) \approx \hat{\varrho}$ with different learning algorithms (e.g. "nearest neighbour" method)

The presented method is to be tested by the relationship between the right and wrong choice of classes (Fig. 3.).

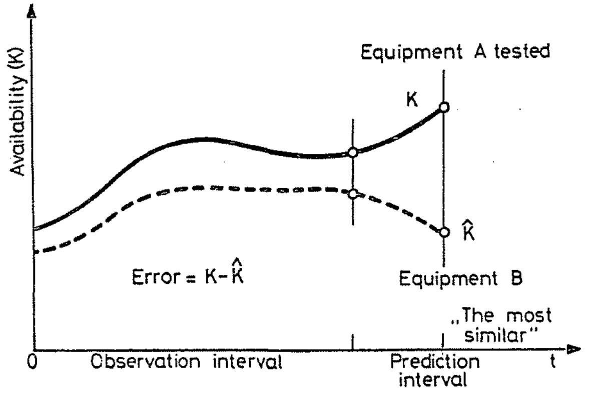

Fig. 3

Industrial applications

1. The field operation data of phone units — type CB 76, manufactured by MECHANIKAI MŰVEK, BUDAPEST — were recorded. (4) The data archives consisted of 331 individual home phone units registered during 4 years including operation, failure, repair time intervals and analysis of failures. The choice of critical subsystems was based on failure analysis (Fig. 4.) Computed with the "nearest neighbour" method the error of the estimated availability being between 0,2% and 0,01% (Fig. 5.)
2. The optimal maintenance strategy of a large production unit was worked out with the help of new ideas based on the pattern recognition method. (5) The general model of operational reliability control is shown on Fig 6. Using different learning

B — Equipment
r — Vector of input effects
$\lambda(t)$ — Output (reliability parameter)
R — Maintenance
d — Decision parameter
e — Control parameter
TR — Generating $\xi(\lambda(t), t)$ random variable
T_M — Pattern

T_A — Learning algorithm
H_0 — Hypothesis testing
E — Computation of checking time

procedures (Bayesian adaptive average, stochastic approximation, inversion method) three classes of estimation can be given for the change of expected value of the failure rate. In the planned checking points and inspection time intervals of

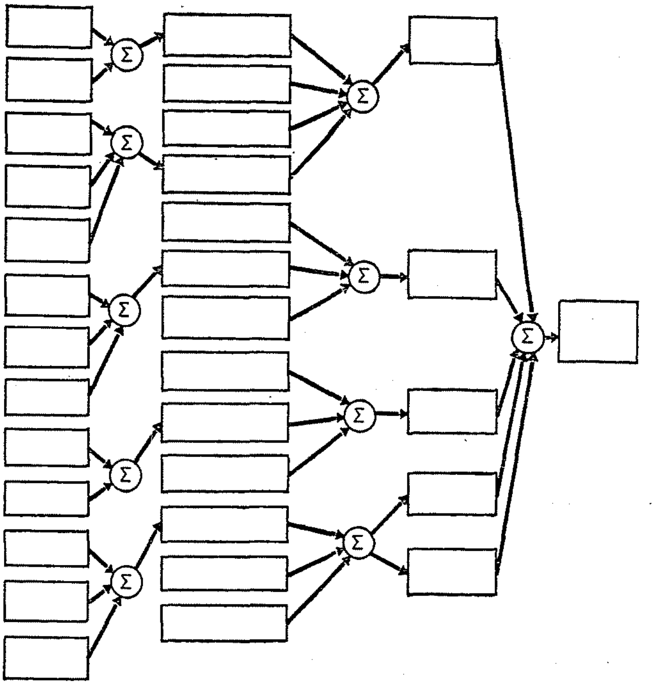

Fig. 4

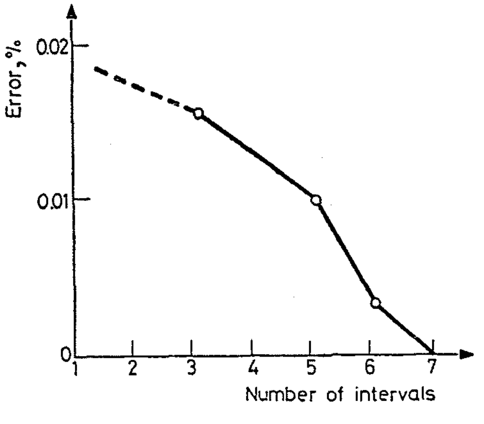

Fig. 5

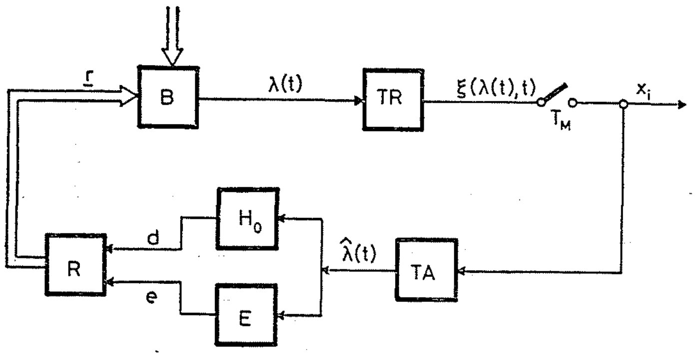

Fig. 6

the operation period depending on the results of prognosed number of failures, an urgent intervention can be initiated if necessary. Being a large production unit in operation the avoidance of a chance of a probable breakdown or even a slight decrease of service maintenance period may effect a significant improvement of productivity.

The effort to introduce pattern recognition methods for reliability forecasting
— using service data from field operation,
combined with optimal maintenance policies,
leads up to more efficient industrial utilization.

References

1. Barta, G.: Accelerated Reliability Testing of Electromechanical Systems. (Dissertation for candidate of science). Budapest,
2. Barta, G.: Reliability Prediction of Electromechanical Systems by Pattern Recognition Method. Test Methods in Electronics Technology. 3rd International Spring Seminar on Electronics Technology. 1979. Balatonfüred.
3. Pertik, O.—Barta, Gy.—Szász, G.: Some Experiences from Reliability Tests of Industrial Products. Proc. of. RELCOMEX Conference on Reliability and Exploitation of Computers. Walbrzych, 1984.
4. Lendvai, M.: Reliability Prediction of Electromechanical Equipments. Dr. tech. dissertation Budapest, 1988.
5. Schönfeld, T. (1985): Some Problems of Controlling Operating-Reliability of Large Systems in Machine Industry. Dissertation for dr. tech. degree, Budapest, 1985.

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