RELIABILITY OF INTEGRATED MATERIAL AND DATA PROCESSING SYSTEMS (IMDP)

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Abstract

The reliability estimation of Integrated and Data Processing Systems because of their complexity and costs requires special methods. In this paper the possibilities to increase reliability, optimum maintenance strategies, real-time monitoring problems are discussed. The general principle of a reliability prediction procedure using mathematical pattern recognition methods is given.

Introduction

Among integrated material and data processing systems (in the following: IMDP), research team of this Department has mainly been concerned with reliability problems of inspection free flexibile manufacturing cells. The research and development work consisted of collecting and developing methods to grant optimum reliability to IMDP, from design to operation. Reliability tests, maintenance planning, etc. of IMDP cannot be carried out with the classical methods, since individual systems should be considered. Individual handling of this systems requires special methods.

Reliability in Design

Reliability is an equipment property just as important as are nominal performance, load capacity, productivity, precision, etc., so the designer is in a key position to develop and increase reliability.

Experience shows IMDP reliability cannot be designed in the general meaning of the word. For a reliable IMDP performance, reliability aspects have to prevail on four hierarchy levels (1), viz.:

— at the level of construction design;
— code processing at the level of data flow;
— at the level of inspection program development, and
— at the level of adaptive identification — in view of failure possibility of the inspection system.

In general, design work comprises two phases. Firstly reliability indices of the prototype of the planned system are defined based on main characteristics of design. Thereafter various modifications are made, expected to provide for reliability expectations.

Four possibilities to increase reliability are known (2):
— use of more reliable parts, components, sub-systems;
— various methods of redundancy;
— optimization of technical maintenance (maintenance-repair) processes; and
— improvement of operational conditions.

Four main methods of redundancy — proper to actual top techniques — are structural, timely, functional and algorithm redundancy.

An essential precondition of design for reliability is availability of authentic data on the expected reliabilities of subsystems, data to be obtained from several sources. Part manufacturers' catalogue data have to be adopted reservedly. Though, laboratory data are likely to underappreciate system component reliabilities. Also information from field experience of an affine speciality and reliability parameters from service data can be used. The most authentic information can be obtained from systematic collection and computer processing of laboratory, field and service data of one's own product. Feedback to the design phase partly safeguards high quality and optimum reliability. Both in the phase of systems design and after completion, prediction of reliability, reliability estimation, is important.

Reliability estimation can be made empirically or analytically. This latter will be considered below.

The analytical method involves a mathematical model to compute the overall reliability of the system based on component reliabilities.

There are several quantitative indices (characteristics) to describe the reliability behaviour of the system. The best system characterisation is determined by the actual operation targets and the application conditions of the system.

Condition-Based Maintenance (CBM)

Safeguarding of the desired operational reliability level is provided by the up-to-date maintenance system.

Sometimes the traditional maintenance methods is not meeting the requirements of safety, scheduled production or economy.

Important economic losses can arise from the maintenance process often performed at a time other than justified by the technical condition of the system. Namely, manufacturing systems grow increasingly sophisticated parts, components involving various physical and chemical processes, exposed to different stresses in operation, multiply. Also operating conditions vary in wide ranges. At the same time, safety regulations specify to prevent failures due to wear, ageing, fatigue, corrosion, by maximizing the operation time up to maintenance according to the so-called 36 rule, if the density function of failure free operation is of e.g. normal distribution (Fig. 1).

That means that in 99.865% of the cases, the component is replaced before its failure (*inutilizing* the full useful life of the components is not utilized), while

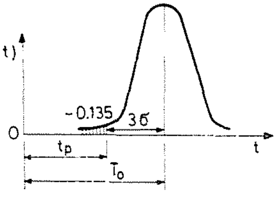

Fig. 1. Method to determine operation interval t_p between repairs. (Normal distribution of failurefree operation)

in 0.135%, failure may nevertheless occur in spite of the intended replacement of components before the mean expected failure time. It can be seen that the strict respect of the planned preventive maintenance does not assure the optimum of safe, planned economic operation.

Value of the failure process parameter of equipment failing other than by wear, ageing, corrosion is constant throughout the operation time. That is, no optimum service time until repair can be specified, imposing to apply latest methods of maintenance planning. Development of the maintenance activity tends to apply CBM methods.

These methods are suitable for a high operational reliability of the equipment, in occurrence of efficient diagnostic methods and means to monitor the equipment and its subsystems, and of specified equipment reliability indices for the case of CBM (3).

Two kinds of CBM strategies are distinguished, namely:

Maintenance Strategy Using Physical Parameters

This strategy imposes an inherent monitor to exist in the considered system, periodically delivering wear characteristics; a cost factor in itself. For a "simple" component such as a failed unit, working condition is easy to check at short intervals. Fore a more complex equipment, e.g. a ship engine, regular diagnostics require great many, expensive instruments, justified, on the other hand, by the high repair costs and the cost excess due to operational uncertainity (4).

CBM strategy is conditioned by knowledge of the predicted characteristic, e.g. variation of a set of parameters, and its measurability.

CBM Strategy Using Reliability Parameters

In the case of CBM using reliability indices, the equipment is operating to failure, without a priori limitation of operation time between repairs. Maintenance operations are expected to eliminate failure consequences. At the same time, the reliability parameter value is inspected at regular calender intervals. Eventually, operating conditions are modified or the equipment is tested in detail.

Conditions of the application of the method are as follows:

1. Failures have no catastrophical consequences;
2. Failures are occuring relatively seldom (high reliability equipment);
3. It is easy to observe and prevent failures (Time and man-power limitations);
4. The maintenance based on the demonstration and the inspection of reliability parameters is economic;
5. The operation is organised (computer, specialists, reliability informations).

Data needed for, and sufficient to, the development of an optimum maintenance system generally are not fully available. Therefore establishment of the CBM strategy is decomposed to three problems:

— data collection;
— using data available, establishment of a "starting", quasi-optimum maintenance system;
— adaptive, dynamic optimization of the "starting" system by means of continuously increasing information.

Introduction of condition-dependent maintenance methods permits full utilization of individual (proper) equipment operabilities without increase of the breakdown probability, at a cost reduction possibility as high as 30%.

Real-Time Monitoring

Real-time monitoring is that made of the system in operation, simultaneous to doing its intended functions, at continuous collection of information specific to its operation. Continuous monitoring of the system while functioning is made so as to affect operation of subsystems performing functional tasks of the system as little as possible. Monitoring devices partly collect data within the system, and partly, they generate thereupon signals to be conceived by observers inside or outside the system. It is determined by the systems technique of the equipment whether intrinsic monitors may be applied, whether the system is able to process signals generated in monitoring, or not. For instance, this is a possibility for stored program-controlled (microprocessor-controlled) equipment. Else, signals can only be processed by an extrinsic monitor. The intrinsic monitor is always mechanical, the extrinsic monitor may be either human or mechanical.

Thus, in real-time monitoring, behaviour of the system in operation can be traced theoretically with no delay.

Practically, there is always some delay between changes of system behaviour parameters and the monitoring of information, a delay depending on characteristics of the system and the monitoring instruments.

Instantaneous pattern of the continuously monitored system characteristic cannot always be considered as information from monitoring. To be accessible and conceivable for the observer, it has to be transformed, may be processed, evaluated, etc. Thus, between sampling and display, there is a timely process in the monitoring tools. Monitoring has to be such that two consecutive sampling times, system-characteristic time-dependent processes, and the interval between sampling and monitoring are coordinated, lest the essential monitored information characteristic of the system gets lost.

Real-time monitoring of the system is expected to produce information truly depicting timely variations of the condition, efficiency, fullness of use, etc. of the system in operation. Thereby the system can be technically diagnosticized, offering data and instructions helping maintenance.

Maintenance of complex systems is efficiently helped by direct instructions from real-time monitoring tools.

In addition to direct instructions to the maintenance, data helping maintenance of the system at a higher level can be formed. There are useful information to users and developers of the system, likely to point out e.g. equipment exploitation, loadability, bottlenecks, weak points etc., and anormal, non-damaging saturation processes. These data stored in adequate form over a longer period can give a basis for reliability indices of the system.

Reliability Prediction by Pattern Recognition

Pattern recognition (statistical classification) involves certain mathematical-statistical methods of concluding from a number n of known variables to another — unknown — variable. There are other possibilities, too, such as regression analysis (linear, nonlinear), and other (e.g. decision theory) methods. These, however, assume knowledge of the statistical model of the tested phenomenon (joint density functions, correlations, etc.).

In actual cases, for multidimensional models, these statistical characteristics are not available. The so-called non-parametric methods, e.g. pattern recognition procedures are used.

In the pattern recognition method, characteristics of the statistical model are replaced by a set of data on known objects, the so-called "*archive*". Computer methods of pattern recognition yield conclusions on an unknown object not yet tested, from data, "experience" in the archive.

Let the state of an arbitrary main unit of the given production system be characterized by the reliability characteristics of the given part units in function of time. The selected reliability characteristics describe the failure rate of a given component or part unit, seriousness of faults, and the general level of servicing.

A system collecting failure data to yield the mentioned reliability parameters for the given product from previous life tests or service data is assumed to exist. Structure of the tested object will now be characterized by suitable codes describing connection, hierarchy of components, part systems, — by the so-called construction matrix. Thereby weak points of the object will be mapped and quantified.

Thereby the problem can be reduced to record variations of several typical parameters — failure rates observed in some sub-systems of the structure.

In occurrence of observed values of the state vector in a given interval, and in knowledge of the timely course of the functioning ability of a sufficient number of equipment vs. observed state characteristics throughout the useful lives, the tested equipment can be classified according to its expected useful life, provided it is exposed to the same, or doubtless similar static and dynamic stresses (nearly identical operational conditions).

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