Dependability Assurance of Industrial Production Processes

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Abstract: The first section of the study defines the functions of dependability assurance, than it gives an overview about the usually used reliability and maintenance analysis. The following chapter demonstrates dependability assurance for industrial production processes. In this chapter is discussed importance of dependability planning and direction, reliability analysis for the production processes, stressed the significance of the Fault Mode and Effects Analysis method. This method identifies the potential process errors, determines the possible effects, and identifies the possible consequences of the production processes in order to decrease the occurrence of error conditions.

Keywords: dependability, reliability, fault, maintainability, availability

1 Functions of dependability assurance

In our days an important component for quality of products is dependability. Strict requirements of dependability on modern electronic devices – long-term error-free operation, durability, reparability, storability – make is necessary to determine also the most important parameters that characterize dependability features beside the most important technical parameters. The process for provision of dependability for devices begins during forming the construction of devices; it continues in the manufacturing phase and extends to dependability checking of ready-made products as well as to accomplishment of operating reliability. The following figure shows the life cycle sections (conception, planning and development, manufacturing, operating and maintenance) with dependability functions (Fig. 1).

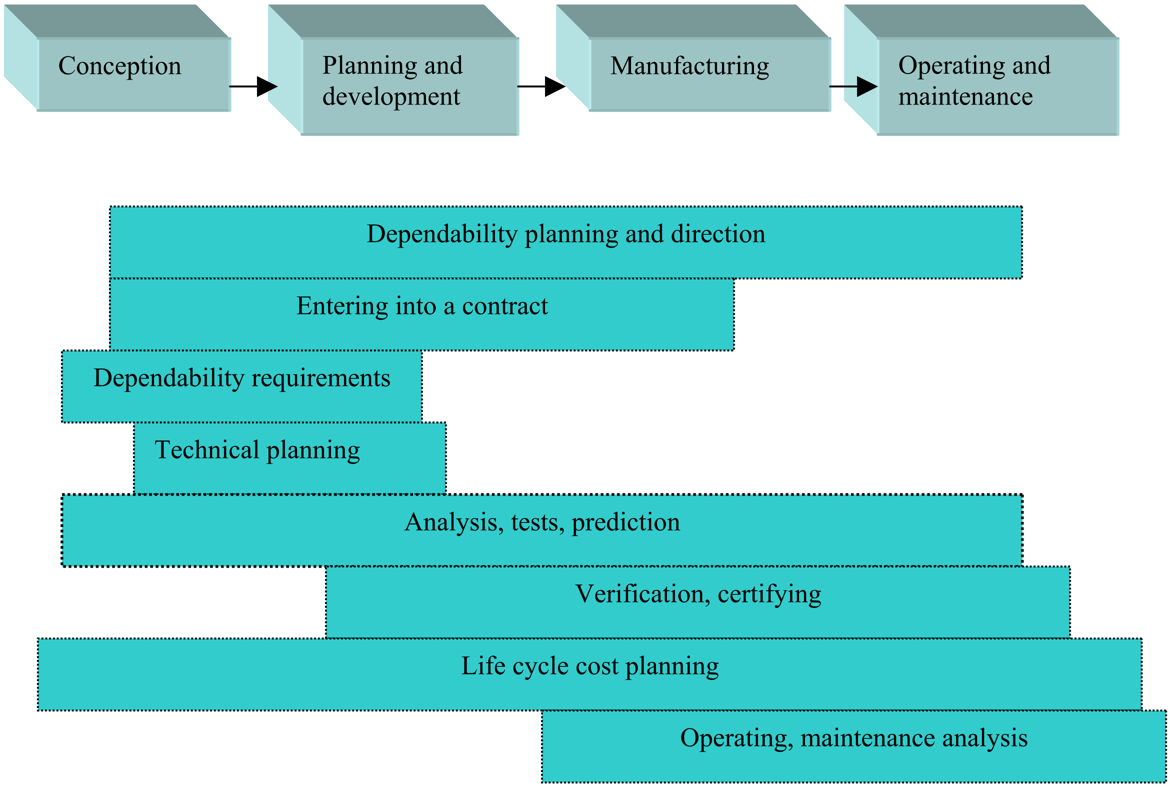

Fig. 1 Functions of dependability assurance

Therefore numerical characterisation of dependability of devices and provision of reliability parameters is a basic requirement on the users' part. Reliability requirements on electronic devices make it necessary to check and determine the reliability parameters and to utilize reliability data in a unified system. Practical realisation of this activity is facilitated by the corresponding standards and technical guidelines. Dependability is a common term that is used to describe usability and factors effecting on it, i.e. reliability, maintainability and maintenance service. This is a common interpretation of reliability used for general description, in case of non-quantitative concepts. The standard in a qualified sense identifies dependability with reliability [1]. Fulfilment of the above requirements can be accomplished by such properly planned and regular activities, measures that can provide some warranty to satisfy reliability and maintainability requirements.

2 Reliability and maintainability analysis procedures

Below, based on the international standard 300-3-1 of International Electrotechnic Committee (IEC) we give an overview about the usually used procedures [2].

- ❖ Fault Mode and Effects Analysis,
- ❖ Fault Tree Analysis,
- ❖ Reliability Block Diagram,
- ❖ Markov Analysis,
- ❖ Reliability Prediction.

1. ***Fault Mode and Effect Analysis*** (FMEA) is suitably especially when we examine what effects have faults of basic materials, parts and equipment on the next functional level of higher order, and what fault mechanism can be established at this level. FMECA (Fault Mode, Effect and Criticality Analysis extends FMEA to criticality analysis by expressing fault effects numerically with the probability of occurrence and grade of heaviness of individual effects. Estimation of probability of a fault must be calculated directly from reliability prognosis, using the data that were estimated by FMEA (probability of occurrence of a fault mode, fault rates etc.) Strictness rate of effects must be evaluated by a prescribed scale.

Advantages:

- o identifies connections between reasons and effects,
- o demonstrates previous unknown event outcomes,
- o it is a systematized analysis.

Disadvantages:

- o number of data can be too much,
- o analysis can be converted into complicated,
- o environment conditions, maintenance respects can be not examine.

2. ***Fault Tree Analysis*** (FTA). This analysis method deals with determination and analysis of conditions and factors that cause an occurrence of a preliminary defined not desired event, or that significantly effect on the operation, safety, economy or other prescribed parameter of the system.

Numerical analysis is performed on the basis of the fault tree. Faultless condition of a system, its usability parameters are estimated using methods of Boolean algebra. Basic data required for calculations are as follows: fault rates of parts, repair rates, probabilities of fault modes etc.

Advantages:

- identifies the logical way of failures,

- demonstrates redundancy systems, logical way of defects,
- prepares ways to failures simply.

Disadvantages:

- very big trees can be because of detailed analysis,
- don't present state transition ways,
- don't examine complicated repair and maintenance strategies.

3. ***Reliability Block Diagram*** (RBD). It is a deductive method to evaluate reliability of a system. RBD gives a graphical analysis of logical structure of the system, on which individual partial systems and/or parts some reliability connections exist. This method allows representing the possible ways of successful operation of the system by those arrays (partial systems/components) the common operation of which is necessary for the operation of the system. There are several methods for evaluation of the reliability diagram. Depending on the type of the system structure, simple Boolean-like methods (that can or can't be led back, divided), analysis of the successful way of operation as well as truth tables can be used to predict the reliability and usability of the system.

Advantages:

- most types of system configuration are demonstrated,
- analyses the combined events,
- values simply functional and non-functional units with Boole-algebra.

Disadvantages:

- don't give cause and effects ways,
- must know reliability functions for every events,
- don't examine complicated repair and maintenance strategies.

4. ***Markov Analysis*** (MA) Markov Analysis is mainly an inductive analysing method; it is suitable for analysing of functionally complex structures and repair-maintenance strategies.

The method uses the theory of Markov processes. Theoretically it evaluates probability of being in a given functional status of system elements (parts, partial systems) or probability of occurrence of given events at given times or periods.

Advantages:

- identifies operating and non-operating state of systems with random variable,
- demonstrates multi-state events,
- values complicated repair events.

Disadvantages:

- because of big number of system-state can be too complicated,
- don't help logical solution of problems,
- supposes constancy of state transition rates.

5**. *Reliability Prediction*** (RP) Reliability Prediction (RP) calculates the reliability of the system from component data; therefore it is common to name it parts count (PC) method. By its character it is an inductive method, and can be used mainly during early planning to estimate approximately the fault rate of the system.

Advantages:

- time and cost claim of analysis is small,
- date are in early construction of devices,
- evaluation of dates can be effect with computer.

Disadvantages:

- precision of prediction is little
- don't analyse fault cause and effects,
- don't examine repair and maintenance strategies.

3 Dependability assurance for industrial production processes

3.1 Dependability planning and direction

At dependability planning of the production processes the customer's demands must be observed. If a product has been produced somewhere else already then the production process itself must be taken over without changes. If in some parts of the process we use different tools (e.g. machine of other type) then we can change the original production process, but some designing rules must be observed.

- Obtaining all necessary information and specification.

- Customer information is made by observing the experiences obtained during the production of similar products and the available equipment and technology, indicating on it the steps of the process, the examination points, cycle times, required labour force and the main tools.
- Making of arrangement plan that shows physical configuration of the production line, the arrangement of tools and machines and operators.
- The design of the product and the bill of material determine the distribution option to be used. Based on the bill of material we must construct the distribution structure of components, observing basic features and parameters of the given process.
- At each critical process step a producing capacity calculation must be performed for the given tool, workplace. E.g.:
    - *Test* The test process to be used, the tools and programs are determined by the customer. Beside this a further checking or testing point can be inserted to make the process checking more effective or to improve the quality and reliability of the product.
    - *Process control.* Critical parts of the process, (e.g.: application of paste, wave soldering, remelting (furnace) are checked with statistical tools to avoid excessive differences.
    - *Documentation* Making of operating and technologic instructions
    - *Tools and methods*. In the first place the customer's offers must be observed. Development of new tools is possible for process stability, more effective checking, facilitation of operator's work or for protection of components.

When determining the number of manual implanting places, the number of components and the time for implanting of individual components must be observed. If we have determined the number of workplaces then the distribution of components between the individual stations follows. For example in electronic industry is production of control cards produced by surface mounting technology that are made for various electronic devices and sold as components or as parts for the producing process built into the completed final product. On the first workplace such components must be implanted that are clogged into the borings on the circuit board. This may be configuration of pin of component or because of using other fixing pins. When using such components there is a possibility to check the pins of components visually by turning of the board. The number of badly implanted components can be decreased by this, too.

Of course, it depends on the number of such types of components, on how workplaces such checking can be performed. The following aspect that determines the implanting sequence is location of components. Implanting of a smaller and a bigger adjacent component must be begun possibly always with the smaller, because in this way the implantation becomes simpler and can be avoided more easily that we move out the other component from its place.

After preparation of the producing process a test production takes place. During test production a number of boards specified by the customer must be produced. Test production is usually performed with the presence of the customer. At this time the production process, the conditions of the production and fulfilment of requirements they demanded are checked. The number of pieces to be produced also has its time of running. This time depends on the number of pieces to be produced and on the complexity of the board and process. At first 5-10 boards must be produced on the production line. If these cards pass the test and are good in quality then a newer amount can be started (about 31 pieces). During test production not high number of pieces but reaching the proper quality is on the first place. After production the given number of pieces the customer subjects the board to various tests, which includes re-testing of boards, visual, x-ray checking by which the quality of soldering is checked.

If the customer is not satisfied with the quality of the boards or with the conditions of the production then he can immediately take the product away or may give a chance for a new test production. In each case they make a report in which the errors are listed that must be repaired until the next test production, and it determines the new date and the number of pieces.

If the customer is satisfied with the quality of the produced board then he gives a permission for continuous production. In case of smaller errors he makes a suggestion on repair of them or only draws the attention on them and requests their elimination. A production line can reach the maximum number of pieces only after a certain time, as the workers working on the line must learn each process, and for this some time is needed. Therefore a certain run-up time is required for this. This is agreed by the employee and the employer before test production.

3.2 Reliability analysis, tests, prediction

In electronic industry, mainly in the area of control boards, development of products has reached an enormous extent. Not only small modifications, but bigger changes, yet complete change of products have become more frequent. As a result of this, not only parts must be replaced relatively quickly, but on the production line smaller or bigger changes must be made more times then previously. Of reliability analysis procedures, FMEA method can properly provide smoothness of changes [3]. Application of the analysis decreases the danger of new possibilities of errors that accompany modifications and the corresponding costs.

The FMEA method can be characterised as a kind of organised group of activities that tries to reach the following targets:

- detection and evaluation of potential errors of a product/process or their effects
- determination of measures that decrease or eliminate the chance of emerging of potential errors
- documenting the process.

If an organisation takes the obligation to a possible continuous development of their products then the necessity of use of FMEA as a regulated technology used for identification and promotion of elimination of possible problems is extremely important.

Although for a person responsible for making of FMEA necessarily a given person must be assigned, collection of FMEA data must be performed within the frames of a team-work. The group should be possibly compiled of experienced specialists, for example of engineers from the area of designing, manufacturing, mounting, repairing, quality and testing.

The FMEA method has two types: the Design and the Process FMEA.[4]. This work does not aim to describe both methods, the Design FMEA was mentioned only for the sake of completeness. PFMEA is an analysing technique that can be used by the engineer/group responsible for manufacture as a tool in order to – at the possible extent – consider and mark the potential error modes and the reasons/mechanisms connected with them. In its most precise form the FMEA is a summary of ideas of the engineer/group (including analysis – based on previous experiences - of those units that possibly may fail), after a process was developed. This systematic view displays and standardises the intellectual activity that is usually performed by an engineer during each production design action.

The process FMEA:

- Identifies the potential process error modes connected with the product
- Determines the possible effects of the errors on the customers
- Identifies the possible consequences of the manufacturing and mounting process and determines operational units on which the checking is focused in order to decrease or detect the occurrence of error conditions.
- It creates a ranked list about the possible error modes, thereby it founds a priority system that serves as a basis for repairing measures.
- Documents the results of the manufacturing or mounting process

Definition of a “customer” in respect of FMEA in a usual case is “end-user”. Nevertheless the customer can be also a subsequent or down-stream manufacturing or mounting operation as well as a service station.

When the FMEA is entirely completed, for the regulation a process FMEA (PFMEA) is required for the new, changed or brought partial processes in all new applications or environments. This is initiated by an engineer from the responsible operation-designing department.

During the process of introduction of PFMEA a requirement from the engineers is to directly and actively embrace the representatives of all concerned areas. These areas must include, not exclusively, the areas of designing, production, quality, reliability, repair and suppliers according to the extent of responsibility of the given area concerning the next operation. Expediently the FMEA as a catalyst should help the exchange of ideas between the concerned functions and thereby it should promote the group work.

PFMEA is a live document before the accomplishment section, or must be introduced parallel with it, before the instrumentation for manufacturing, and all manufacturing operations must be calculated, beginning from the individual components to mounting. Early overview and analysis of new or corrected processes facilitates the prognosis of possible process errors, their solution or checking during the work phases of manufacture designing of a new model or component program.

The task of PFMEA is to provide that the construction of the product equals with the design target. Those potential errors that emerge because of design imperfection can but must not necessarily be included in PFMEA. The impact and avoidance of these are included in the construction FMEA.

PFMEA does not rely on the changing of the product design to defeat the weaknesses in the process, but observes the characteristics of the construction of the product concerning the planned manufacture or mounting to provide that the produced product satisfies the customers' demand and expectations as much as possible.

FMEA regulation provides some help also for development of new machines or equipment. Methodology is identical, although during developing of the machine or equipment the product must be considered as well. If the potential possibilities of error are known, correcting measures can be taken in order to eliminate them or continuously decrease the chance of their occurrence.

PFMEA must be started with the flowchart of the given operation and with the corresponding risk evaluation. In the process description the features of the product/process must be determined associated with each operation. If there is a possibility, it is expedient to indicate from the proper constructional FMEA some effects corresponding to the product. Flowchart/risk evaluation examples used for making of FMEA constitute a part of the analysis.

In order to facilitate documenting of analysis of potential errors and their consequences, a PFMEA protocol format was created, the filling-out of which must be performed the following way:

- FMEA number,
- Unit,
- Responsible for operation,
- Made by ,
- Model/type/year,
- Key date,
- FMEA date,
- Group,
- Function of the operation, its requirements,
- Error option,
- Errors may result in,
- Seriousness,
- Classification,
- Possible cause of /mechanism of the error,
- Frequency,
- Present process control,
- Discoverability,
- Risk factor (RPN),
- Suggested measures,
- Responsibility,
- Measures,
- Modified RPN,
- Checking.

If the error possibilities were ranked by the RPN then corrective measures must be taken firstly in case of problems or units that were given the highest value. If, for example the reasons are not entirely clear then determination of the suggested measure, can be performed on the basis of experiments that were planned according to statistical aspects. The aim of all suggested measure is to decrease the value of seriousness, occurrence and/or detection.

In all such cases where the effect of the established error possibility may endanger the manufacturing/mounting person, a correcting measure must be taken in order to prevent the emerging of the error by eliminating or checking the cause(s) or provide proper protection for the worker.

The necessity of specific, correct measures and those with measurable usefulness and measures connected to other activities can not be stressed enough. FMEA value of a profoundly considered, and properly developed process without limited place, and effective correcting measures. Always the concerned activities have the responsibility to execute the effective programs for all suggestions.

Conclusions

In electronic industry, development of products has reached an enormous extent. Not only small modifications, but bigger changes, yet complete change of products have become more frequent. As a result of this, not only parts must be replaced relatively quickly, but on the production line smaller or bigger changes must be made more times then previously. Of reliability analysis procedures, FMEA method can properly provide smoothness of changes. To increase the probability of fault detection, the process and/or design must be revised. Generally the extension of checking tools is costly and ineffective in respect of development of quality and reliability. Increase of frequency of checking is not a proper correcting measure, it can be used only as a temporary tool, and a final correcting measure is required. In several cases the change of the design of the given part may be necessary to promote the detection. It may be that in the interests of increase of probability some modification must be executed in the system. Nevertheless the prevention of errors (decrease of occurrences) and not their detection must be stressed.

References

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