Field data reliability analysis of highly reliable item

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Abstract

In recent years the effect of electronic elements has become more and more significant in many areas of human activity. Automotive engineering is one of the areas which have been also importantly affected.
The paper deals with dependability namely reliability analysis procedure of a highly reliable item. The procedure described in the paper is based on the thorough data analysis aiming at the operating and manufacturing of these electronic elements.
The main purpose of the paper is to present one method of reliability analyses of highly reliable items. To describe the procedure and ways of reliability measures determination is the main aim of the paper. Consequent purpose of the paper is to address possibilities for risk assessment in terms of the primary inputs coming from the reliability analyses. The information about degree of risk is very crucial in such application. More over we do have real data which have been calculated and might be used for the risk assessment process. Risk assessment principles are to be understood properly and used in proper manner.

Key Words: Highly reliable item, reliability analysis, risk assessment possibilities

1. Introduction

In the paper we are going to address reliability assessment of a highly reliable electronic item. In this paper the evaluated application is perceived as an item produced for systems´ specific use/utilization. Item is implemented in a system in order to control one of the step functions of the system. For similar work and standardised approaches see e.g. [6], [7] or [3].
The manufacturer has had long term experience of item manufacturing. This item is also widely introduced into the market where it successfully meets the parameters within technical applications. The introduced item has been applied in the systems´ environment many times and no major problems have been detected regarding its function. All terms are in accordance with the [2].

As we know the item is initialised by start power. Unfortunately non-intentional causes resulted in non-compliance with the manufacturing process during development and manufacturing a new item. While manufacturing the item a relatively minor shortening of program protocol took place, thereby shortening the initialisation time. This situation resulted in the production of many of incorrectly manufactured items where the initialisation time was shortened by the program. The non-compliance with the manufacturing process was detected only by accident and that was after some time. However, most of the items manufactured this way have been mounted in systems and they have been in operation.
The non-compliance with the manufacturing process itself, thereby shortening the programming time might

not be a serious problem. More related circumstances might be the real problem. The first one is the fact that the items have been mounted in systems and they have been in operation. Another quite serious problem is the fact that an item function failure can result in failure occurrence on the device which is supposed to perform a system's step function. If a system step function is just being used, its interruption-failure might lead to a critical accident with serious consequences. In case this type failure occurs, it affects significantly system's dependability. Moreover, it breaks the confidence in the step function which leads to the lack of confidence in a system as a whole.

Resulting from the arguments mentioned above the producer decided to solve the problem immediately. The producer wanted to find out if the errors occurring when manufacturing items have a possible effect upon operational dependability – reliability. Basically a few solutions could have been taken into account at that moment. Finally two of the solutions were chosen to be accomplished.

One of the options is to carry out a one-side interval calculation of a item reliability measure at a required confidence level. This intention is easy to be fulfilled since the data on the item operation was carefully and systematically collected. The aim of the paper is to describe a measure calculation procedure and assess statistically if testing of an available data set is suitable.

2. Field data assessment procedure

The procedure follows widely known and basic approaches and terminology. The producer provided data on the item operation over a complete period. Regarding the nature of the analysis the following facts were agreed on:

1) The aim of the analysis was to calculate the one-side item reliability interval. The item "programmed incorrectly" was assessed first, and the item "programmed correctly" was assessed as the second. The calculation of a reliability one-side interval determined for each set separately was the outcome of the analysis.
2) The next step was to compare both items sets and decide whether the „incorrect programming" can/cannot affect the item reliability. A one-side interval was determined at a required confidence level and it specifies a minimal reliability level of an item set obtained by a calculation.
3) The operation time of the item started the moment a production range was delivered plus two weeks (the assumption that it will be delivered to the customer, mounting into the system, and physical start of the operation).
4) The real operation time equivalent was determined by recommending the standard GS 95003-1 ([1]) and is based on a calendar time. The real operation time started the moment as stated in point 3). The transforming coefficient value following the sources/standards mentioned above is: dormant time versus operation time ≈ 24,836 : 1.
5) The standard IEC 60605-4 "Equipment reliability testing - Part 4: Statistical procedures for exponential distribution - Point estimates, confidence intervals, prediction intervals and tolerance intervals" has been used for calculating the reliability measure one-side interval at a required confidence level.
6) The reliability confidence interval was set according to common roles. One of the very accurate levels which were decided to be used is 95%. This level was used for following calculations.
7) End of observation, censoring by time is given by the date of 31st December 2008. This was negotiated with the item producer.
8) The hour [h] is a reliability measure unit.

Since the standard IEC 60605-4 deals with a few possible types of the assessed sets, it is necessary to determine what type it is

referred to. The operation profile and the agreement that the analysis assessment will be finished on a certain day indicate that this is a case of a specific field test finished by time without replacing the item. This assumption resulted in the following solution taking into account the standard mentioned above and well known authors in this field like [6], [7] or [8].

Following the standard IEC 60605-4 recommendation a lower limit of mean time to failure at the required confidence level was calculated. In order to estimate one-side interval of a lower level of mean time to failure we used the following equation:

$$m_{l\,F/C} = \frac{2T^{*F/C}}{c^2_{a,n}} \qquad (1)$$

where:

$m_{l\,F/C}$ - is a lower limit of mean time to failure of either „*F*“ – „incorrectly“ programmed sets or „*C*“ – „correctly“ programmed sets.

$T^{*F/C}$ - is accumulated operation time of all items sets (either „*F*“ – „incorrectly“ programmed or „*C*“ – „correctly“ programmed) observed in the operation during an evaluation period. It is calculated using the equation $T^{*F/C} = \sum_{t=i}^{n} t_i^{F/C}$ („t_i“ = real operation time of all items of *i*-th production range of either „*F*“ – „incorrectly“ programmed sets or „*C*“ – „correctly“ programmed sets. The interval is the period in which they are put into operation which lasts up to the day when the temporary observation is finished.

$c^2_{a,n}$ - chi square for a given number of degrees of freedom ν; „*a*“ – confidence level agreed on 95%.

Since it is a one side censored set (it is censored by the agreed date when the observation is to be finished; this date is the last possible day when the operation record is to be made), the number of degrees of freedom ν to determine chi square is going to be calculated using the standard IEC 60605-4 recommendation following the formula:

$$\nu = 2r^{F/C} + 1 \qquad (2)$$

where:

r is a number of events (failures) in a given group of sets.

Based on the assumptions and the calculation which have been made before, the reliability measure values for correctly and incorrectly programmed items were found. These values were calculated at the required confidence level. By comparing these values we were able to determine whether the error affects the item reliability during a manufacturing process.

However, concerning the field data we face a theoretical problem. The data set is apparently different concerning a digit place in terms of the operation time of the item sets. It means that correctly manufactured items obviously operate for a shorter time than the ones manufactured incorrectly. This situation can affect a calculation procedure as well as a comparison of the results. Taking into account this situation it is necessary to test the field data using the statistical test which is supposed to prove their comparability. The results of the test are mentioned in another paper named “Statistical comparing of reliability of two sets of highly reliable items”. The objective of the statistical analyses is to compare two sets of data both of which have non-similar size. The next presumption is the exponential distribution of both sets – this is fulfilled as the sets consist from electronic items where we do presume the exponential distribution of the failure occurrence. We may use more approaches for the statistical test. The examples are: test using binomial distribution, test using *F*-distribution or Weibull test. The testing and mathematical application is very specific in all respects.

Unfortunately there is no space in this paper for presenting the results.

2.1. Example of the application of above mentioned procedure

Here will be presented restricted part of the above mentioned procedure. The procedure given in this example is the same as used in the whole analysis. The difference is that no information about portion of data or other relevant indicators will be provided.

Data were provided in following form:
Number of production range: 1.
Number of items produced in this range: 4 200
Date of production: 16.1. 2006
Number of failed items in this range: 1
Date of failure: 12.10. 2006

Ad section 2, point 3), 4), 7), 8):
Number of days in operation: 43 days
Number of hours in operation for 4 199 items: 1030 h
For 1 item: 238 h
Total hours in operation for all items from this range: 4 325 710 h

Following the calculation (1) and (2) it is:
$\nu = 2r^{F/C} + 1 = 2.1 + 1 = 3$
the value of chi-square is standardises and can be found in tables. The value of chi-square for 3 degrees of freedom is approximately 7,8. Therefore the next calculation is as follows:

$$m_l = \frac{2.T^*}{c^2_{a,n}} = \frac{2\,.\,4\,325\,710}{7{,}8} \cong 1109\,156 \cong 1.10^6\,h$$

It means that lover limit of one side confidence interval for MTTF of the item is approximately 1.10^6 *h*.
The assessment of the other sets which represent the electronic items made (both correctly and incorrectly manufactured) is carried out in the same way. Finally the decision about the failure rate comparability is performed. From the reason of keeping the industrial confidence of the data and their assessment we can not present full range of the calculations made. We can only present that the difference between correctly and incorrectly manufactured items is noticeable.

3. Risk analysis resulting from the failure occurrence

In this phase of observing the object we are talking about partially predictive risk assessment. We could choose fully theoretical way, but the field data are available so there is no need to do it. Following the theoretical approach we would focus on individual risk contributors which would be thoroughly examined. The classic probability methods would be used for determining the event occurrence probability. The expert assessment based on the defined scales would be used for analysing the consequences. Usually we do not count on other factors when dealing with theoretical risk analysis. However, some special characteristics still exist and that is the reason why one of the possible approaches where another factor occurs is described below. However, further verification and validation of the obtained result will pose a problem while assessing the risk theoretically. In our case, when undesired event occurrence probability might be recorded when observing the field data, the result will be more realistic and consequent verification of the result will be also possible. Such event occurrence information is not a prediction then, but it is estimation based on the real information. Consequence decisions resulting from the occurred event might be regarded as a prediction in this case. Consequences description options are stated in many well known standards. Using either fully standardised approach, namely automotive standards or software support can be another option when analysing the risk. An event occurrence rate or its criticality may be obtained using well known dependability analysis methods, e.g. FMECA, PHA or OSHA. The total risk is usually based on these two contributors we often work with in

industry practice. Concerning software support when analysing the risk it is possible to use widely available tools, e.g. Risk Spectrum based on the FTA method supported by the ETA method, or the tools by Relia Soft or Item Software – Item QRAS which uses both methods individually but basically leads to the same result.

Using so called soft methods when analysing the risk and dependability is another possibility. It is namely about non-stochastic methods which are based mostly on the deterministic approach and iteration principles. Also the probability plays an important role but most approaches of these methods are based just on empiricism and practice. We would highly recommend fuzzy logic which allows us to work very well with qualitative characteristics of some events, and which is able to quantify them. If we were to define individual process states in system operation and they would represent the periods in which the system is run, we would be able to determine to what extent the event belongs to a defined state while an event occurs. That is how we would cover the failure criticality level regarding the defined states set and the time vector in which a system might occur during its operation/technical life. Unfortunately, in this paper there is no space for presentation and development of this approach.

Generally speaking we can use standardized criteria by which every failure is evaluated following the previously defined scales. Using the point estimations the Risk Priority Number is added to each failure mode. The *RPN* is then used for downward arrangement of the assessed failures. The failures with a risk number going above the defined scale undergo the corrective actions which are supposed to reduce the risk number sufficiently.

3.1 Evaluated factors

The existing model described in standards (e.g. IEC 60812:2006 MIL-STD-1629a) considers two evaluated factors, Probability – *P* and Severity – *S*, or three evaluated factors, Probability, Detection and Failure Consequences. These factors result from a fully quantitative assessment where the risk is expressed by a conjunction of probability and consequences. The formula for it is as follows:

$$R = P * S \tag{3}$$

The Detection Factor – *D* in a full quantitative assessment would decrease the probability that a failure will not be detected during design/manufacturing process (see e.g.[4]), thus the mathematical expression is as follows:

$$R = P * D * S \tag{4}$$

whereas its value would belong to the interval < 0;1 > (or < 0 ; 100% >).

4. Conclusion

The procedure as described above was used to calculate reliability of the single sets which served as correctly and incorrectly programmed items. Following the obtained results a possible effect of a manufacturing error upon the items reliability was estimated. Following the results it is obvious that manufacturing error could affect items reliability in some way. Both sets are from the statistical point of view slightly different, which is an essential piece of information. This fact should be referred to when carrying out statistical data evaluation using the introduced tools.

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References:

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