
A NEW METHOD FOR THE APPLICATION OF RAMS TECHNIQUES TO QUALITY ASSURANCE (QA)

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Abstract

The application of RAMS techniques in all the phases of the lifecycle of each type of installation will surely guarantee its adequate exploitation in terms of production continuity and quality of the obtained products in the respect of prefixed constraints on the security of the working staff, safety and environment impact. In this frame, a particular importance must be attributed to the use of those techniques as support to quality assurance applied in the planning and building phases of the installation and of the products obtained by it. The present paper will include a short description of a method for the application of those techniques in this phase of the lifecycle and of the results that may be obtained by its application in shoes manufacturing, in particular those types where the technical requirements are higher, as it is the cases of certified products like “safety” footwear.

Key Words

Reliability, availability, quality assurance, risk assessment.

1. INTRODUCTION

Recently the discipline of Reliability, Availability, Maintainability and Safety (RAMS) techniques has changed from the traditional role of predicting reliability to that of involvement with the process of verification and validation of production lines and of their products.

By this way, the application of RAMS techniques in all the phases of the lifecycle of the assets and their products should contribute to obtain an amelioration of their quality (in terms of their safety, reliability, maintainability and availability) and a decrease of the production costs with a consequent improvement of their competitiveness.

In particular they should allow the achievement of the following main results:

- improvement of the quality, reliability and safety of the considered asset by the application of a suitable quality assurance program during all its design, planning and building phases;
- demonstration that the asset may be adequately exploited avoiding risks connected with working staff security, safety and environment impact;
- decrease of the production costs by an improvement of the quality of the production lines and of their connection and by a correct definition and improvement of the maintenance planning to be applied on them involving a more efficient use of existing capacity;
- make available advanced techniques allowing savings in the production by improving “lean manufacturing” and a “just-in-time adaptation” of the production lines to the quick changes of the market requests and trends.

2. AN INNOVATIVE SOFTWARE TOOL FOR THE APPLICATION OF RAMS TECHNIQUES ON INDUSTRY

In order to obtain the above results, ENEA (an important Italian Research Institute) is promoting, in collaboration with some industries, the development of a software tool for the application of RAMS techniques in normal industrial field besides the advanced ones (in fact, up to now, their use is limited to advanced fields such as nuclear, aerospace, etc. and for risk and safety analysis).

To this aim it will be constituted by the following main software methods and devices:

- a database for the recording of exploitation and test data;
- methods for the processing of reliability data on their basis;
- methods for the selection of the components on which maintenance must be applied and for its preliminary definition;
- methods for the system reliability analysis;
- methods for the application of RAMS techniques as support to quality assurance.

The database is a fundamental device in the application of all the software tool. In fact it must allow the achievement of important results such as a feedback of experience and the processing of meaningful and personalised reliability data.

Concerning the experience feedback that may be obtained by the enquiry of the data recorded in it, as better explained in the following, it has a fundamental importance in order to improve so the quality of the asset taken into consideration as its exploitation especially referring to the maintenance to be applied in such phase of the lifecycle. An adequate reliability and/or availability analysis cannot be left apart of the availability of meaningful reliability data on the components constituting the system taken into consideration; those data may be found in the literature, but this type of data doesn't take into consideration the particular exploitation conditions to which the interested components are submitted with the consequence that they don't allow the obtaining of meaningful results in particular analyses such as maintenance improvement or quality assurance. This type of data may be only obtained by the processing of suitable exploitation data previously collected on the components or component piece parts constituting the system taken into consideration.

To this aim a database component oriented will be developed. In order to obtain the results mentioned above it will be constituted by different files allowing the recording of the following information:

- univocal identification of the component and of its constituting parts not only in terms of their initials but also of their engineering characteristics, normative applied in their planning, building and testing, environment and operating conditions;
- recording of data on the results of possible tests carried-out on the component after its building;
- recording of information on the failures occurred on each component during its exploitation;
- recording of information on each maintenance (preventive programmed maintenance or failure repair) carried-out on the components so identified.

The database will be interactively connected with suitable computer programs for the data entry and for the enquiry of the recorded data. Concerning the data entry, the set-up program will include the possibility so of a transfer of data from other databases as the manual recording by the operators who collect the information. The enquiry program will be developed so that the end-user may obtain datasets to be used for the reliability data processing or for a direct exploitation feedback on the basis of his necessities: details on the subjects will be reported in the following.

In order to obtain meaningful reliability data starting from the rough data recorded in the database, suitable processing methods will be developed. In particular methods based on the classic so as on the bayesian statistics will be set-up so that the processing will be possible also in the case that very few rough exploitation data are available. In this frame methods approximating the main statistics functions and allowing the processing of each type of reliability data (failure rates, repair times, etc.) will be developed. To this aim suitable homogeneous datasets obtained on a particular component type by the enquiry of the information recorded in the database (see above) will be used. At last further methods for the statistical analysis of imprecisely recorded data will be also set-up: they will meet the need arising from the practical observation that real field data very often cannot be precisely recorded; to this aim an original methodology linking mathematical statistics with the theory of fuzzy sets will be developed.

As better explained in the following, the reliability data so obtained will be used for different applications of RAMS techniques such as maintenance definition and improvement, support to quality assurance, risk assessment and system reliability analysis, etc.

The methods for the system reliability analysis included in the main software tool must allow the achievement of the following main results:

- demonstrate, in the design and planning phase, that the product will surely satisfy requested quality and reliability requirements;
- execution of a suitable safety analysis and risk assessment in order to demonstrate that the considered system (installation, equipment, etc.) will surely satisfy the requested requirements in terms of security of the operating staff, safety, environment impact, etc;
- improvement of the maintenance planning at system level by the research of the best maintenance configuration corresponding to the minimum management costs and maximum availability.

In order to obtain those results, two different methods, respectively based on Monte Carlo or analytical techniques have been developed. The first type of techniques allow a realistic simulation of the system also in presence of failure rates varying in the time and a consequent realistic evaluation of quantities such as availability or management costs, etc.: it follows that the code developed on their basis will be the best solution to face problems connected with the maintenance improvement. On the contrary the use of analytical techniques will allow a best evaluation of reliability: it follows that a code based on the use of such a type of techniques will constitute a valid support for the execution of safety and risk assessment or of other analyses in which the evaluation of reliability is a critical factor.

Maintenance is a critical factor in the management of each type of industrial system in consideration of its influence on availability, safety and management costs. The introduction of reliability criteria in the maintenance definition and improvement may surely contribute to the amelioration of those quantities. To this aim, the software tool in reference will include a suitable method allowing the application of innovative criteria such as the selection of the only components on which maintenance must be applied on the basis of their importance in the system in which they operate and of the time trend of their total failure rate or the preliminary definition of the maintenance strategies to be applied on the components so selected on the basis of such time trend of the failure rate: by this way many useless and repeated maintenance operations will be eliminated with positive effects on the system availability and management costs. Besides, the maintenance strategies so defined component by component will be improved at system level by the methods for the system reliability analysis in order to find the best maintenance configuration corresponding to the minimum of the management costs and maximum availability in the respect of prefixed constraints on safety, environment impact, etc

In fact maintenance must be carried-out on the components constituting a system in order to prevent the intervention of systematic failure causes which would surely generate the failure of the component (and the consequent increase of their failure rate) in a short time. On this basis it is a non-sense to apply preventive maintenance on components only having a decreasing and/or constant failure rate (their failure probability would not change after the maintenance execution). On the contrary maintenance must be surely applied on components having an increasing trend of the failure rate in their life in order to eliminate, before their intervention, the systematic failure causes generating such increase. Equally maintenance must not be carried-out on components not important in the system operation in order to avoid useless money consumption (in this case the waiting of the component failure and its repair is convenient). It follows that the code that will be developed will allow the automatic analysis of the time trend of the total failure rate of each component (previously processed by the methods described above on the basis of the exploitation data recorded in the database) and of its importance: on this basis the code will allow an automatic selection of the only components having an increasing total failure rate and important in the system operation as the only ones on which maintenance must be applied. In particular a suspension of the maintenance provided on components having only constant failure rate will be advised in order to wait for the time at which it becomes increasing because of the intervention of systematic failure causes. Once the components on which maintenance must be applied have been so selected, the developed method will allow the definition of the maintenance strategies to be applied on them on the basis of the operations necessary to eliminate, before their intervention, the systematic failure causes generating the increasing of the total failure rate and of the time trend of the correspondent failure rates: the time at which the increasing failure rate calculated for each systematic failure cause crosses the constant one corresponding to random failures is advised to apply the preventive maintenance operation necessary to eliminate such systematic failure cause. Besides, the code will

carry-out a comparison between the costs of each maintenance and of the failures to be avoided by it: such a comparison will allow to verify if the execution of maintenance is convenient in comparison with the waiting of the failure.

In order to obtain the results described above, the data recorded in the database will be adequately enquired so obtaining a suitable experience feedback and the failure rates calculated for each failure cause (random causes included) will be exploited. By this way an innovative FMECA (Failure Mode Effect Cause Analysis) method will be developed.

At last the main software tool will include the method described in details in the following chapter allowing the application of RAMS techniques as support to the quality assurance applied on the assets and on their products during their planning, building and first exploitation phases.

3. THE METHOD FOR THE APPLICATION OF RAMS TECHNIQUES TO QUALITY ASSURANCE

In the following figure 1 the main phases of the planning, building and first exploitation of each type of item are reported together with their possible interactions with RAMS.

Usually ISO/CEN standards are applied to draw the specifications of the product to be obtained; besides, CAD/CAM tools are followed to plan and manufacture it. In those phases internationally tested norms and standards are strictly applied so that a prefixed quality of the product must be guaranteed.

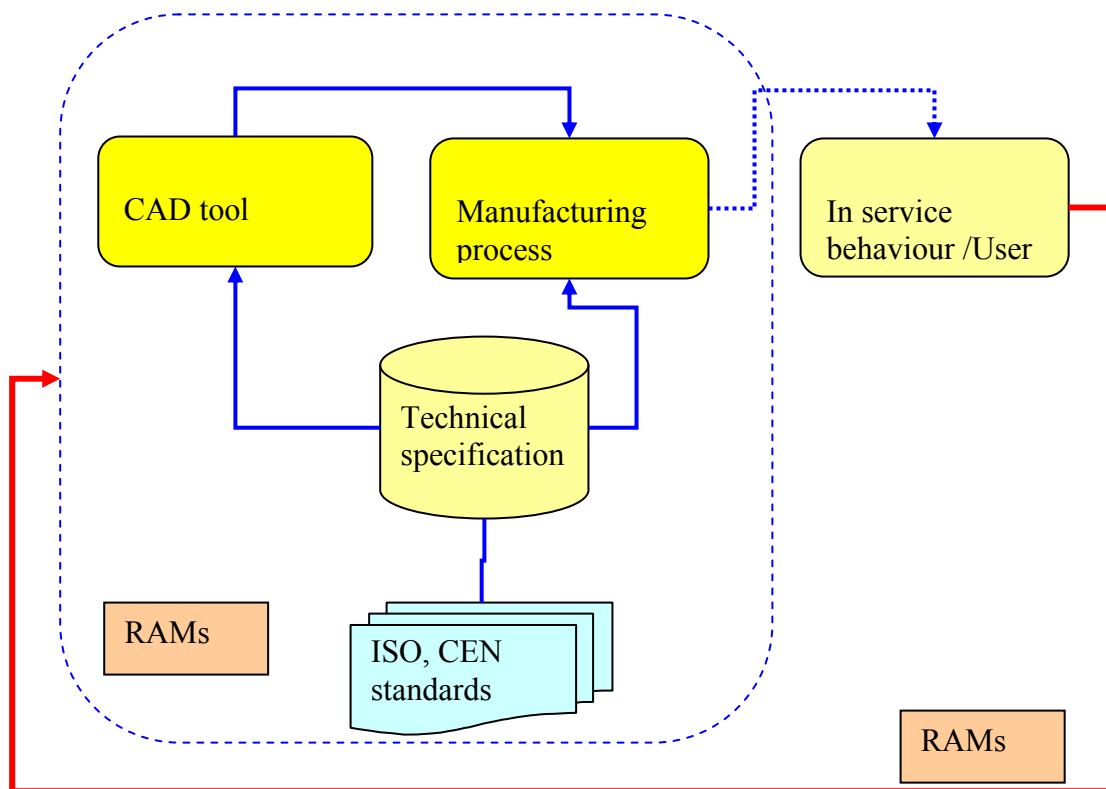


Figure 1. Areas of possible application of RAMs techniques

The method to be developed must allow the integration of RAMS techniques with those CAD/CAM systems: by its systematic application an amelioration of the design of the products, also including an adequate definition of trials, should be obtained. The final goal is the integration of RAMS techniques within design stages of products which are required to satisfy any technical requisites related to quality, safety, etc. Modules, to be considered in the proposed software are: materials requirements, performance requirements, design parameters, link with QA system.

In fact an adequate planning and building of each type of product cannot be left apart of statistics and reliability techniques.

First of all the design of a product must be “robust”, where “robust design” means the obtaining of optimal performance of the product simultaneously with variation in manufacturing and field conditions. To this aim requested performance requirements of the product must be singled-out together with the factors which allow the achievement of those performances and, consequently, characterise them; the designers should specify target values of those factors and their possible tolerances so that the performance of the product in the field is not affected by variability in manufacturing or field conditions: suitable demonstrations must be carried-out to this aim. Besides, tests must be defined allowing the verification that the product has been realised respecting the nominal values of those factors with the consequence that the requested performances have been achieved. The execution of the above demonstrations, the interpretation of those tests and the verification that requested performances have been achieved necessarily involve the use of statistics techniques.

In any case, the verification that the requested performance requirements have been achieved does not guarantee that the product will have a long service life with few failures: traditional efforts of design, although necessary for the reasons expressed above, are often not sufficient to achieve both the functional performance requirements and a low rate of failures with time. To prevent these failures (i. e., to achieve a high reliability of the product), a specific “reliability program” must be applied during all the life-cycle of the product with particular reference to its planning and manufacturing. Such reliability program typically includes the following activities: setting overall reliability goals, apportionment of the reliability goals, stress analysis, identification of critical parts, failure mode and effect analysis, reliability prediction, design review, selection of suppliers, control of reliability during manufacturing, reliability testing, failure reporting and corrective action system.

On the basis of what reported above, referring to the design and manufacturing phases (see the part on the left of the fig. 1), RAMS techniques should allow the achievement of the following main results: first, an “a priori” verification that the target values of the factors characterising the performances of the product and the tolerance range around such a target value allow the achievement of those performances; besides, activities such as a setting of overall reliability goals, an identification of critical parts, a failure mode and effect analysis and a reliability prediction (consisting of an evaluation of the reliability of the product so demonstrating that prefixed requirements of the item to be produced will be guaranteed) should be carried-out in such a phase. To this aim the different methods and devices constituting the main software tool and described in the previous paragraph will be exploited: concerning the first results summarised above, the statistics methods will be applied; reliability data found in literature (or otherwise) on components similar to the ones constituting the item in reference, and the system reliability analysis codes will be used to “predict” the reliability and availability of the produced item. If safety requirements must be respected in its utilisation, a suitable safety analysis and risk assessment will be also carried-out by those codes during the planning phase.

Once the item has been manufactured, suitable tests will be carried-out on it to verify if the prefixed quality and reliability requirements have been achieved. Suitable records will be provided in the database to store the results of those tests. Besides, the statistics methods summarised in the previous paragraph will be applied to interpret the results of those tests. Tests are usually carried-out on a sample of products of the same type in order to achieve the following main types of results:

- control that prefixed quantities characterising the product are comprised within prefixed limits and that the results obtained may be extrapolated to the population that will be brought in the market;
- demonstrate that prefixed performance requirements may be achieved if the measured values of the factors characterising such performances are included within prefixed tolerance ranges;
- single-out possible failures due to “infant mortality”;
- evaluate the reliability of the product on the basis of the failures occurred during the tests.

While good results may be obtained by the tests in the carrying-out of the above controls and in the singling-out of defects generating infant mortality, only a preliminary evaluation of the product reliability may be obtained by them.

On the contrary, more realistic results in the field of reliability evaluation may be obtained by a systematic recording of the results obtained during the exploitation or use of the product (see part on the right of fig.1) and by their interpretation on the basis of a systematic application of the above statistics methods (and system reliability analysis codes if the item is a complex system).

First of all, only the exploitation of the products allows a complete detection of failures usually known as infant mortality and due to defects generated by errors in the planning, inadequacy of the materials or of the techniques applied in the manufacturing: in fact, only partial information in the field may be obtained by the tests mentioned above. As better explained in the following, from a deep analysis of those failures, important suggestions may be obtained on modifications to be introduced into the various phases of the production in order to improve the quality and reliability of the obtained product. In such a frame, a fundamental importance is assumed by the evaluation of the time variation of the decreasing failure rate in the first phase of the exploitation (infant mortality) and by a qualified recording of the exploitation data into the database so that meaningful reliability data may be processed on their basis. The analysis of those failure rates and of the data recorded in the database (beginning from the information recorded on the techniques and materials used and applied in the manufacturing of the product up to the causes and modes of the failures) should allow the obtaining of suggestions on modifications to be introduced into the materials and into the design parameters in order to improve such a product. Obviously a first information will be obtained by its first exploitation but an iterative application of the methodology is advised: to this aim new data should be recorded (and successively processed and analysed) on the exploitation of the new product obtained after the introduction of those modifications so that the amelioration obtained by their introduction will be quantified; in this frame the different values of the failure rates obtained at each new application must be compared. The results so progressively obtained will also suggest important modifications to be introduced into the testing trials to be applied on the product so that it may be improved before its launch into the market. In fact the presence of only a defect in few items of a stock involves the restitution of all the stock with consequent high loss of money.

Besides, the processing of the exploitation data progressively recorded in the database allows the obtaining of realistic reliability data (failure rates, middle time to failure, etc.) on the product obtained and a consequent realistic evaluation of its reliability: to this aim the methods for the reliability data processing will be exploited together with the system reliability analysis codes if the product is complex and constituted by more components.

A further method will be developed which will allow an automatic use of the methods and devices constituting the main software tool in order to obtain the results summarised above in the frame of the application of RAMS techniques as support to quality assurance.

In particular such development will involve:

- the verification that the available software methods and devices (database, statistics methods, methods for the system reliability analysis) constituting the main methodology and described in the previous chapter are enough for the achievement of the provided results. If they are not, singling-out of further methods that must be developed to this aim and their consequent development;
- an arrangement of the files constituting the database so that it will allow an adequate recording of the data necessary for the execution of the analyses described above such as tests interpretation, identification of the modifications to be introduced into planning and building of the products in order to limit or avoid their infant mortality, and so on;
- an adequate interface of the existing methods listed above so that their quick and end-user friendly application will be possible in order to allow the application of RAMS techniques to quality assurance in the terms summarised above;
- an exact definition of the analyses to be carried-out for such application of RAMS techniques to quality assurance and of the procedures to be followed in order to realise the results of those analyses (modifications to be introduced into the planning and manufacturing of the product and into the constituting materials, etc.). In this frame an integration of those techniques with the project systems adopted (CAD/CAM, etc.) will be also developed, providing designers of new products a valuable tool which could be considered as a virtual tester.

4. APPLICATION EXAMPLE ON SHOES MANUFACTURING INDUSTRY

Once the development of the above method will be completed in the terms described in the previous chapter, it will be tested by its application on existing industrial systems.

In this frame it will be also applied on safety shoes manufacturing. As said, the sw tool described in the present paper is yet in a development phase: it follows the presentation of results on the subject is not yet possible. In any case it is interesting to analyse in this paper the results that should be obtained by the application of the method subject of the previous chapter also because the manufactory in reference will directly take part in its development.

The final goal to be obtained should be the integration of RAMS techniques with CAD/CAM systems applied for shoes and components design in all the stages of such design with particular reference to safety shoes (i. e. a particular type of shoes used by workers and subject to European Directive of IPE - Individual Protective Equipment): by a systematic application of the method an amelioration of the design of the products also including an adequate definition of trials to be carried-out to this aim should be obtained. The importance of the use of such a technique relies in the fact that the legal responsibility of any accident/injury to workers is automatically affecting any providing company (footwear maker) in certain cases: so the sale of a pair of safety shoes is just the beginning of a process of accepting responsibilities for which no tools are available in the market.

The footwear design process, usually carried out by design specialists, is a complex process of several stages which requires detailed knowledge of footwear, both the shoe and the production, and the current fashion tendencies. Footwear design understands, apart from developing the design for a shoe, the development of the engineering drawings and the selection of the most appropriate last and the definition of technical specifications of the final product. The short lifecycle of a product such as a safety shoe (less than 1 year in-service) and its character of "passive" element of relative low cost and mass produced, makes the application of sophisticated techniques such as RAMS quite complex and expansive today. Even more, after sales are done, no relevant information of the product feeds-back the manufacturer, once the shoes are "in use". Anyway, in future markets where the "service and functionality" aspects of consumer goods (shoes) which have to fulfil very specific technical requirements during their use by consumers, RAMS or an evolution of them could support the product control along its lifecycle and a clear added value for the end users.

RAMS concepts are intended to be incorporated inside or close to CAD tools, putting intelligence into a product which many times is only checked throughout trial-error processes.

Referring to the diagram of figure 1, an area where actually lifecycle concepts are not really used is the use of the product by the consumer (in-service period, see the part on the right of the diagram), where no relevant information goes back to the manufacturer, except specific market complaints due to failure of the shoe. In any case, the presence of few defects rising in the first period of the life of a product involves the restitution of all the stock in which those few failed shoes were included. Independently of the money losses due to such restitution, the presence of those defects has a very negative effect on the image of the producer and on the competitiveness of his products. It follows that particular importance is assumed by a continuous contact between the producer and the customers so that the first one may take into account information on defects and failures found by the second ones, analyse them and introduce suitable modifications (in the planning, materials, etc.) and consequently improve his products. In this frame the RAMS techniques, applied as described in the previous chapter (see the database and the methods for the reliability data processing), could add value to shoes in generals and in particular to safety shoes, during the design-manufacturing stage (singling-out of the causes of the defects, consequent intervention into the materials, manufacturing processes, etc. in order to avoid those defects and to improve the quality of the product).

Problems caused by inadequate footwear are a significant cause of workplace absenteeism in companies. The cause-effect relationship is clear, but it is neither direct nor quantifiable. Although the prevention of foot problems and the use of the right footwear is fundamental, there is only one standard (UNE 23 087) that deals with safety footwear through impact studies. A few studies, like the "Safety footwear against mechanical risks: Guides for the election, use and maintenance" by the Spanish Workplace Health and Hygiene Institute (INSHT,) condense scattered information on this type of footwear.

An additional element which justifies the application of RAMS, is the legal responsibility of the safety shoe manufacturer in case of worker accident, as safety shoe is a protective element which has to fulfil the functionality for which it was designed and manufactured. In this frame RAMS techniques may be used to carry-out suitable safety studies: starting from the singling-out of the failures with consequences to the user security that may occur, they should allow the singling-out of the protections or planning devices necessary to avoid them. Besides, the failure rates that may be processed on the basis of those occurred failures will allow an "a priori" evaluation of the reliability of the product obtained so contributing to its qualification.

At last RAMS techniques will also be applied in the terms described in the previous paragraph in order to improve the design parameters and their tolerances so that the provided performance requirements are achieved.

5. CONCLUSIONS

The main features of a method for the systematic use of RAMS techniques as support to quality assurance have been described in the previous chapters: it may be applied to each type of product contributing to the improvement of its quality and reliability. In particular, the results that may be obtained by its application on shoes manufacturing (with particular reference to “safety shoes”) demonstrate how the method may contribute not only to improve the quality of the product obtained but also to avoid its failures and the consequent risks; to this aim a fundamental importance is assumed by the application of RAMS techniques during all the planning and building phases so contributing to the obtaining of a robust design and, besides, in the execution of suitable safety and risk analysis also carried-out on the basis of the exploitation feedback supplied by the end-users. Obviously such logic may be applied on each type of asset, beginning from the products of a manufacturing industry up to each type of plant, installation, etc.

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