IMPORTANCE OF THE RELIABILITY REQUIREMENTS EVALUATION IN THE INITIAL PHASES OF THE DEVELOPMENT OF AN EQUIPMENT FOR THE MECHANIZATION OF THE MARICULTURE

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Abstract. *The importance of considering reliability aspects in the initial phases of the product development process has increased more and more, because in these phases the impact of changes in the project is smaller and alterations can more easily be executed. In this work, was presented an exploratory analysis of how the reliability can be evaluated in the initial phases of the product development process with the use of tools like Ishikawa's diagram, FMEA and check-list. As a practical application of the presented analysis, were accompanied the initial phases of the development of the prototype of a machine for the mechanization of a specific oysters cultivation task, the cleaning of lantern net, structures used to keep the oysters in the sea isolated from other organisms. For the prototype development a traditional product development methodology was used, wich deals with the development process in a systematic form, subdividing it in four phases: (a) informational; (b) conceptual; (c) preliminary and (d) detailed phase. The consideration of reliability aspects in the informational phase assisted in the generation of product requirements, guiding the designers to capture the real customers requirements.*

Keywords*: reliability, product development, mechanization of mariculture*

1. Introduction

Nowadays in the complex task of developing products, the importance of reliability in the developed products has become each time more important, as much for the quality improvement of these products as lower development costs. It happens due the solution and prevention of problems in the initial phases of the project, where the impact of changes in the project is lower and project alterations are easier to be executed.

Although reliability has been sufficiently spread out in some specific areas as the aeronautics, nuclear and electronic, in mechanics it has not happened yet. This area is mainly affected by the scarcity of information about the failure rate of many items. Due mainly to economic and methodological problems, there are few items that are tested until the failure (Lewis, 1994) apud (Dias, 2004).

That is the reason why a relative lack of considering aspects of reliability and methodologies by designers in mechanical systems is perceived, at least conscientiously, because it is well known that all designers worry about related basic aspects of reliability. The Figure 1 illustrates some of these ideas, which, in general, do not consider the factor "time" for their analysis (Almeida, 1999). Further, other complementary studies about project methodologies have also shown that reliability aspect is not focused in an explicit way, in the respective phases that compose such methodologies (Almeida, 1999).

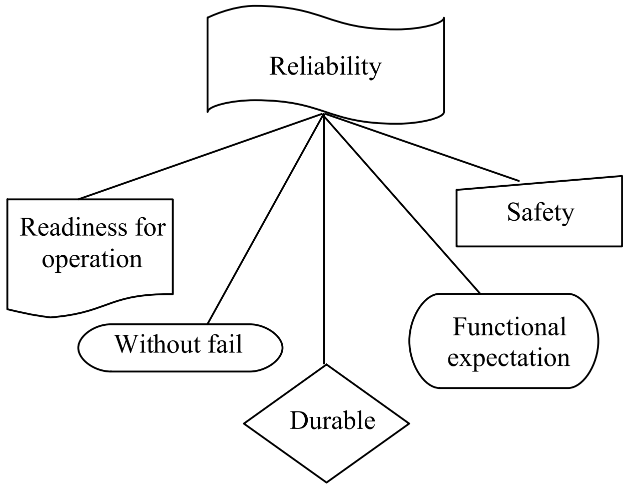

Figure 1 – Ideas related to reliability (adapted of Almeida, 1999).

The purpose of this paper was to verify the importance of considering aspects of reliability in the initial phases of a current project, where these aspects had not been analyzed in explicit way. Applying techniques related to the Design for Reliability (DFR), not only lack of such aspects was identified but also reliability requirements were purposed. In order to do that, the initial phase's documentation of this current project was analyzed and pertinent tools for the analysis of reliability were applied. The requirements obtained from this analysis were compared with the previously definitive requirements and its potential related to the possible increase of the reliability in the project was evaluated.

2. Definition of reliability

Reliability is an inherent characteristic of a system as well as the capacity or power (Kapur, 1973). According to Blanchard (1990), reliability can be defined simply as the probability that a system or product will work in a satisfactory way for a specific period of time, when used under specific conditions.

From this definition, four basic structures can be distinguished: probability, satisfactory performance, period of time and operation conditions. These four structures are very important, because each one is significant in the determination of the reliability of a system or product. This article was based on the analysis of these four structures in relation to the initial phases of the chosen project.

The first structure, probability, provides a numerical form to determine the reliability. It is related to the intuitive notion about the frequency that the system fails. It is interesting to notice that this probabilistic notion always admits the failure possibility.

The second structure in the reliability definition is the satisfactory performance of a system, indicating that a specific criterion must be established to determine what will be considered acceptable in the fulfillment of the function of the system. For such, it is necessary to determine a set of qualitative and quantitative factors.

The third structure, time, represent a parameter through that the performance rate can be measured. The time is used to quantify the probability of the system to complete its mission as predetermined. Reliability often is defined in terms of MTTF (Mean Time To Failure) and MTBF (Mean Time Between Failure). So, the structure time becomes essential to the quantification of the reliability.

The structure operational conditions complete the concept of reliability and specify the conditions under which the equipment will operate. These conditions include environmental and geographic factors, operation's profile, temperature cycles, humidity, vibration, shocks, etc. These conditions not only have to refer to the period in which the equipment will be in functioning, but also they must include the form as the it is storage and transported, because sometimes storage, transportation and manipulation can be more significant for the reliability than other factors.

3. Project description

In order to completely compare the obtainment of requirements focusing on reliability and a project where these requirements had been treated implicitly, the work developed by Santana and Forcellini (2005) on a project for the mechanization of the mariculture was taken as example. In the mentioned project, the requirements had been gotten by techniques that allowed identifying the requirement of the external customers, once internal and intermediate customers were not defined due the non existence of a similar product.

Thus, an interview guide was elaborated in order to enable interviewing the oyster producers (external customers) in accordance with a standard, keeping the focus of the interview, without taking off the freedom of the interviewed and with the possibility to personalize the questions in accordance with the characteristics presented in during the interviews (Santana et al, 2004).

Analyzing the customers responses was possible to establish the customers and afterwards, with the aid of QFD (Quality Function Deployment), the project requirements, as shown on the Tab. 1

Table 1 – Project requirements (Santana et al, 2004).

Requirements	Undesirable Aspects
1. Clean fouling	Stress in the oysters due cleaning time
2. Force to clean the fouling	Damage the oysters
3. Not to damage the oysters	Damages above the expected
4. Fastening to ship	To unbalance the boat
5. Collector of residues	Fouling fixing on the oysters again
6. Water proof	To wet components that are not water proof
7. Low weight	To unbalance the boat
8. Size	Not fit to the boat
9. Price	Compromise the quality of the system and the performance
10.Corrosion resistance	Excessive expenses with materials and increase of weight of the system
11.Resistance to sea water	Excessive expenses with materials and increase of weight of the system
12.Be transportable	Difficulty to carry the system by only one person
13. Production cost	Compromise the quality of the system and the performance
14. Maintenance cost	Reduction in the interval between maintenances
15. Limits of contaminant	Pollution of the culture place and law infraction
16. Material cost	Compromise the quality of the system and the performance
17. Operation cost	Compromise the quality of the system and the performance
18. Material not toxic	Not to compromise the functional performance
19. Number of components	Reduction of the number of components not to compromise the functional performance
20. Useful time	Use expensive or rare materials, increase parts dimensions, use small tolerances
21. Simple interface	Not permit be operated by not instructed persons
22. Failure rate	To fail during use
23. Time between maintenance	Difficult manual assembly, increase production cost
24. Standardized components	The search for standardized components should not limit innovative solutions
25. Operation force	Not permit be operated by only one person
26. Usual processes	The search for usual processes should not limit innovative solutions
27. Recycled materials	Should not limit functional performance

4. Reliability evaluation in the initial phases of the project

An important point to be remembered dealing with the relation between the reliability and the project is that the reliability is an inherent characteristic to the project and therefore must be taken in consideration during all its phases. Considering reliability of a product means develop techniques capable to minimize the impact of the variability in the designed conditions of the product (Dias, 2004).

According to the product development model adopted, it is in the initial phase of development of a product that occurs the survey of customer's requirements and the definition of the project requirements. It is very important specifying reliability requirements adequately during this phase, therefore they will be used as reference during all the cycle of life of product (Billington, 1983, Blanchard, 1990, Almeida, 1999) (it is important to remember that there is a relation between how much of the capital of the project is influenced by decisions in the initial stages of the project).

Thus, it is clear the necessity of defining reliability requirements. This implies not only in defining reliability parameters, through an adjusted measurement, as MTTF or MTBF, but also in finding requirements and orientations that in a first analysis would pass unobserved, and would hinder, in more advanced project process phases, that interactions could be taken in consideration that in another way would reduce the reliability the product.

The identification of these orientations or other requirements is difficult, therefore they normally are not apparent in the customers and designers requirements, mainly referring to the orientations for the selection of solutions inherently more trustworthy.

In this section, it is shown some techniques that can later or earlier be used during the initial phases of the project. They not only allow the definition of reliability requirements but also the discovery of some aspects about other requirements that had not been considered previously through traditional methodologies.

A characteristic of the most methods of reliability evaluation is that these are associates to the determination of failure modes of specific components (a compressor or an axle) and to the analysis of the causes associates to these modes. Dealing with the initial phases of the project, it is not possible to identify failure modes of specific components, because there isn't a definite solution. However, there are some methods that can be applied (sometimes with some modifications) in these phases. Among these methods are the FMEA, the Ishikawa's diagrams and check-lists.

4.1. FMEA

Accordance to Sakurada (2001), FMEA is a qualitative method that studies the possible failure modes of the components, systems, projects and processes and the respective effect generated from these failure modes. In general, the execution of the FMEA depends on the deep knowledge of the structure of the system, and only can be applied in the most advanced project phases. However, considering a functional approach for the failure modes it is possible to apply the FMEA in the initial phases of the project. This approach allows the FMEA to be up dated in an iterative form during all the life cycle of the project.

Because FMEA represents a formalization of the hole knowledge that the project team has on the product being projected, and because at the end of each meeting for the elaboration of the FMEA usually a list with recommendations for improvement is produced. FMEA can be considered as an extremely powerful tool to increase the reliability of the final product. However, as negative points can be cited long meetings time and difficulties during the phase of implantation of the tool.

4.2. Ishikawa's diagrams

The Ishikawa's diagram is a simple tool, almost intuitive, that can be used to organize the activities of brainstorming. It consists basically of a diagram that relates an effect to its causes, and can later be refined to find the causes of the causes, and so on. A variation of this diagram, consists of a diagram where some main causes had already been identified (Fig. 2), guiding the reasoning process.

This approach presents two advantages. First, because it is a method very little formalized, it does not restrict the creativity of the team/designer that is using it. Second, it works as an orientation that allows relating factors that had not been considered previously, sometimes even little related to the effect in study, but that are important inside of the general target of the project. Also it is a method that does not require much information to be used, being therefore ideal for the initial phases of the project.

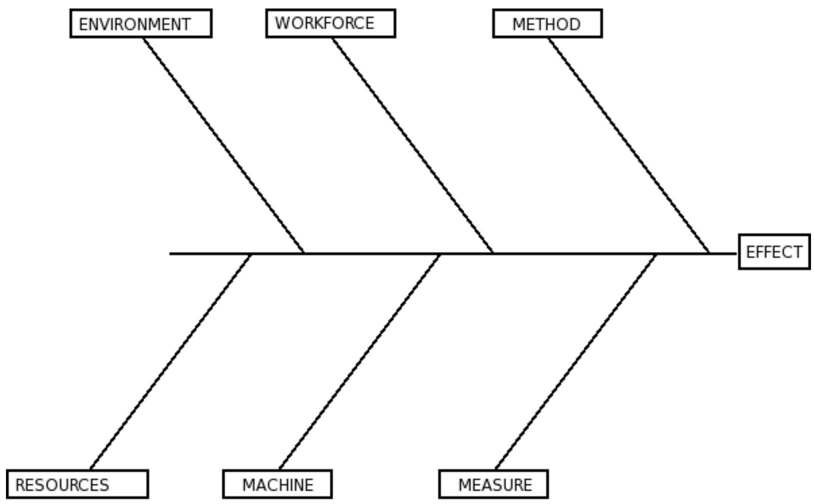

Figure 2 - Ishikawa's diagram.

4.3. Check-lists

It is an extremely simple method that uses a list with a series of items related to the reliability that must be checked if they had been or not considered in the project. Lists obtained from books can be used, that are specific on reliability or not, or the lists can iteratively be created inside of the organization, representing the experience that the organization acquired (inside of a knowledge management process). This last one represents the ideal case, therefore it considers the specific idiosyncrasies of the type (or types) of product designed by the organization.

This method must be approached in a little formal way. If exists a list or a table that designers consider that can assist them, it must be used. It can also be used as a base for a list that will be constructed slowly by the project team, as the experience are being accumulated. As example of the use of these lists, it is shown in Santana (2004) a check-list that approaches a series of aspects, between them the reliability. In Almeida (1999) some lists that focus the reliability problem specifically were considered. In the next section an example of the application of the two last techniques will be shown to the problem presented in the previous section.

5. Examples of use

5.1. Ishikawa 's diagram

To evaluate the application of the Ishikawa's diagrams, two functional requirements had been chosen of Tab. 1, it was considered their failure in the fulfillment of these requirements and was made a briefing brainstorming on them. The first analyzed requirement was the problem of failure at fastening to ship. Below the generated diagram is shown.

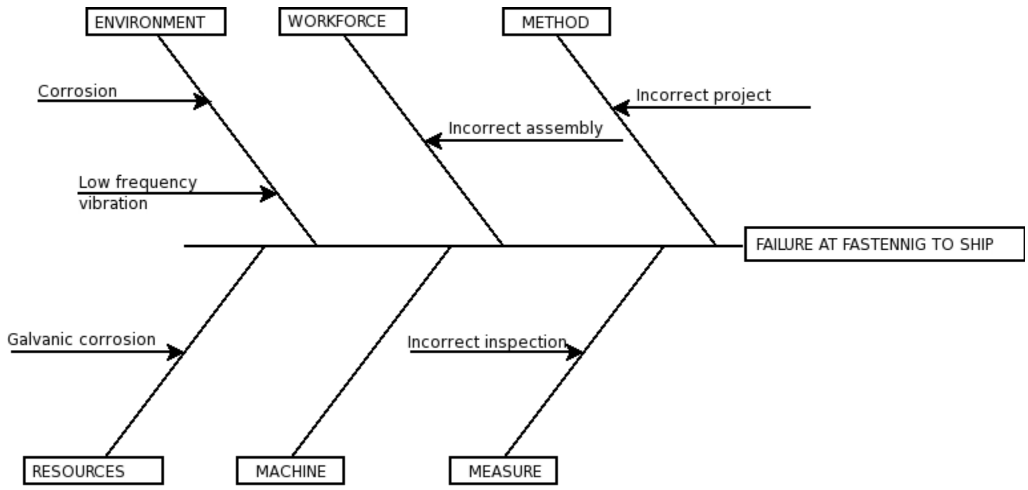

Figure 3 – Ishikawa's diagram for fastening to ship.

The diagram showed quickly, in less than ten minutes, a problem that had not been considered previously. The problem of galvanic corrosion was not mentioned at any moment in the initial project, and however, it is a very important factor to be taken in consideration during the phase of synthesis of the solution, for all its interaction with the saline environment.

The next diagram considers the causes of the failure in fulfilling the function clean fouling, also taken from Tab. 1.

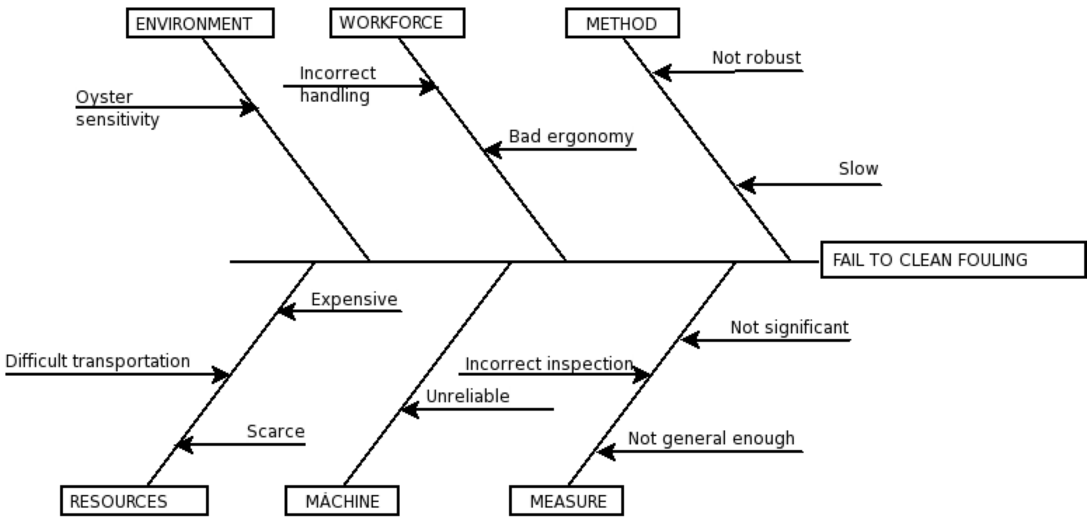

Figure 4 – Ishikawa's diagram for clean fouling.

This diagram has already been beneficial regarding to reliability requirements. It shows the ergonomic problem of the product that had previously not been considered. It also shows the aspects of efficiency measurement of the fouling removal method. These aspects had also not been considered previously, and actually they influence the metric of reliability that will be used.

It can be concluded that the use of Ishikawa's diagrams was sufficiently beneficial for the reliability requirements. In an extremely short time, at least three aspects that had not yet been considered in the process were identified. It did not take more than 20 minutes to compose these two diagrams, working in two people, talking through instantaneous messages system. Also because it is a fast and simple method, it can be used by any team, independently of the level of training of the individuals, differently to a FMEA, for example.

5.2. Check-lists

In this case two concepts were used. First, it evaluated the requirements that consist of the check-list presented by Santana et al (2004), in the Tab. 1. This list is classified as a general list, that does not deal with specific aspects of reliability, but that allowed considering aspects not considered before or considered only implicitly. Second, each one of the requirements were classified according to relevancy of the structures of reliability, as it was explained in section 2, in order to facilitate the agreement and the positioning of the requirement in relation to the reliability of the project. Thus, it can be seen in Tab. 2 how the original parameters (Tab.1) are related with the reliability structures and the justification of such relation:

Table 2 - Relation between the parameters of reliability and the basic structures of the definition.

Structure	Parameter	Justification
Probability	Functional independence between items	These parameters will have bigger impact in reliability modeling, or either, its variations will cause more significant alterations in this structure.
	Number of components	
	Manufacture process	
Satisfactory performance	Desired security	Here is compared the final result with the desired, if this parameter was not the expected, represents a system failure
Period of time		
Operation conditions	Failure risk by bad use	By dealing with an aggressive environment, the environment conditions become a key point in the reliability of the system, once that the materials employed and the constructive form has to support such adversity.
	Easiness to identify and diagnose failures	
	Training for maintenance	
	Easiness to clean	

All the parameters influences in the quantitative analysis of the reliability, but, as shown above, some of them have also to do with other structures of the definition and this correlation allows a clearer visualization of how each parameter affects the reliability of the system.

6. Conclusion

Considering the results presented in the previous section, it can be perceived that the techniques had taken to the identification of orientations and aspects of reliability that had not been considered previously in the project process. These aspects can be developed in more requisites for the project and orientations for later phases of the project process.

It is also clear that the non sensible application of these techniques can cause a high increase of the amount of requirements that can make the project process excessively long and expensive. It is necessary to balance the amount of time and the complexity generated in the initial phase of the project. However, considering the quality in the project process, it is interesting trying to obtain an exhausting list of requirements, so that, during the process of selection of these requirements, the designers can be sure that all the space of possibilities was enclosed. It is during this process that the essential requirements for the project reliability will be identified.

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