INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

CONTINUOUS DESIGN FMEA – PROPOSAL FOR A NEW PERSPECTIVE ON FMEA

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ABSTRACT

This paper presents a method that assists in concept evaluation during the conceptual design phase, called the continuous FMEA tool. The use of this tool allows for better execution of integrated design, including the use of concurrent engineering, because it involves a design team in diverse stages of the product lifecycle. The proposed method includes a bibliographical survey regarding the use of the FMEA, and this study lays a theoretical base for the structure of the method. Therefore, we evaluated the method by means of a case study that pointed to positive aspects of the technique. These include simplicity of application and recognition of the best solution principles according to reliability criteria beyond the reduction of subjectivity in the selection of the concepts.

Keywords: continuous design FMEA, evaluation, product design, conceptual design, design tools

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1 INTRODUCTION

The Failure Modes and Effect Analysis (FMEA) method was developed to assist in diagnosing and forecasting of equipment failure. It is a standardized analytical method used to detect and eliminate potential problems in a systematic and thorough way (Helman, 1995 apud Ferrari et al, 2001). Moreover, it is a tool that uses the knowledge of the design team to improve product quality and performance because many failures can be addressed in the design and/or production process. FMEA allows one to evaluate failure causes and it also establishes parameters for preventative or corrective actions (Helman, 1995 apud Ferrari et al, 2001). Another definition is presented by Sakurada (2001), according to which FMEA "is a qualitative method that studies the possible failure modes of the components, systems, designs, and processes and their effects."

This method consists in to define the systems failure modes and to quantify them from the perspective of their severity, occurrence tax and detection facility. There are scales to quantify each one of these metrics and the associated values are used to calculate the Priority Risk Number (PRN) to each failure mode. So, it is possible to identify the critical failure modes and to priorize their solution (Figure 1).

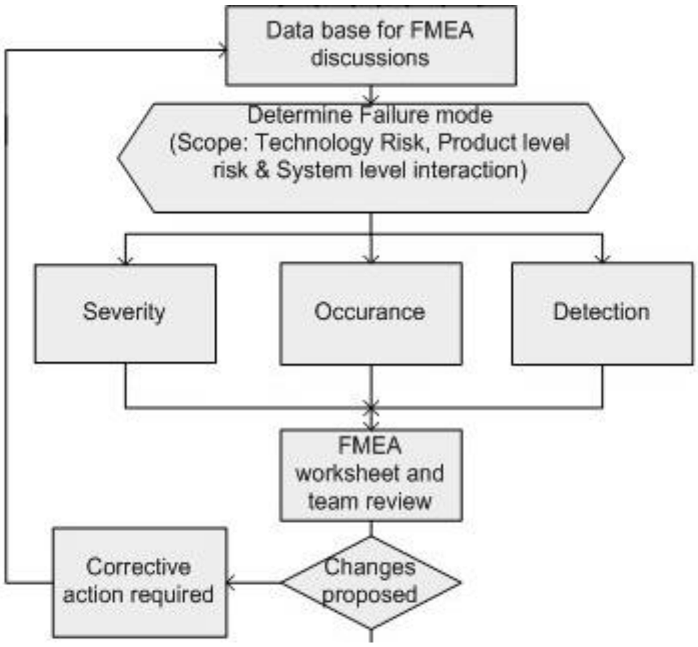

Figure 1. Traditional Design FMEA (adapted from Vilakathara, 2013)

Due to its predictive character, FMEA has recently been applied to product design. When FMEA is applied during the design phase, the product's critical points may be foreseen. These critical points can be since potential failure focus to fault focus. According Del Frate (2012), "a fault is the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources". Also, Stamatis (2003) points that "failure is the inability of the system, design, process, service, or subsystem to perform based on the design intent".

This view allows the design team, through the effect and failure modes analysis, to define corrective actions during the design phase and to prioritize the sizing and selection of component materials. However, the application of FMEA is still questioned by many organizations.

This paper presents a new way to perform FMEA in which the design team applies this tool from the conceptual design phase to the detailed design phase to prevent design faults or failures and potential service failures of the products. This new way of using FMEA aims to correct some disadvantages of traditional FMEA that will be described in the next section.

2 LITERATURE REVIEW

FMEA is a method used in many ways during product design. Many papers describe different tricks in the development of this tool, but many problems remain in its application. According to Tumer et al

(2003), FMEA is considered "(...) laborious and with costs in economic and time aspects. Moreover, many applications have unsatisfactory results in its application due to inconsistent descriptions of functions of component systems and their imperfections."

However, the authors state that "the increase in the importance of the reliability metric is increasing the improvement of prediction methods, especially those used in new designs." O’Halloran et al (2011) present a method of reliability analysis using function-flow failure rates in the early design stages. This method search to calculate the system reliability by the functional diagram blocks arrangement. However, the proposition is based in component repository data to be applied. It is a good way to develop redesign and non-inovative systems.

Another characteristic of traditional FMEA is criticized by Pillay and Wang (2003). They argue that the severity, frequency, and detection scales can cause distortions in the Priority Risk Number (PRN). According to the authors, due to the linearity of the scales proposed, an item with a high severity failure degree can have a lower PRN than another item with a high occurrence and detection failure degree.

There is yet another limitation to the application of FMEA related to the multiple failure classes that are treated with this method. Multiple failures, according to Rausand and Øien (1996), correspond to those failures that possess a dependence relationship with other failure modes. These authors subdivide these dependent failure modes into two main groups: failures with common causes and failures in cascade. The first kind is defined as failures that possess the same cause, and the second kind is defined as failures that are the result of the failure of another component or system (Rausand and Øien, 1996).

According to Hawkins and Woollons (1998), there are two FMEA design approaches. The first is a hardware approach that evaluates the changes that occur in each component in terms of behavior change. The second is a functional approach that can be adopted in the initial phases of the design process and considers information related to the specified intentions and functions of each part of the equipment. Additionally, according to the authors, the first approach is carried through when the design is sufficiently developed, while the second is used when the design is at an incipient stage. From this perspective, several authors have considered various forms of applying FMEA to the early phases of the design process. Arcidiacono et al (2003) considered the use of the FMEA along with other design techniques for axiomatic design in the early phases. Due to this advance, the authors state that FMEA is applied in a simpler way because many failure modes are prevented due to the efforts expended before the archetype construction.

For application in the Conceptual Design phase, FMEA possesses the advantage of detecting the failure earlier and at the level of functions. In this way, the design team will be able to decide how to solve the problem at a lower cost. However, its use at the beginning of the design phase must still deal with the disadvantage of little available information, which can be a source of uncertainties. Despite this, the FMEA must be applied in an environment of integrated product development.

Kmenta et al (1999) conducted a study of the Advanced FMEA (AFMEA) application in which they claim that: "(…) the Advanced FMEA aims to solve some of the deficiencies associated with the traditional FMEA. AFMEA uses the behavior modeling to simulate operations of the device and to help the reasoning of causes and effects." They also point out that the AFMEA can be based on the analysis of the components or functions.

Hata et al (2000) point out that: "(...) the relations between components have an important role in fulfilling the functions." The authors also consider a model that evaluates the many questions of function fulfillment, designer intention, geometry, and system assembly with the aid of CAD systems.

The authors have developed a model system for determining failures; this system creates a map from the designer intentions to the failure modes while also considering the functional relationships between the components beyond the information of geometry, assembly, constraints, and features that compose the product. Another positive aspect is that modeling functional chains allows teams to identify possible failures in the component interfaces.

Another possibility for FMEA application in the early phases of product design is presented by Hari and Weiss (1999) who developed a model called Conceptual Failure Modes Analysis (CFMA). This method is presented as an FMEA for the requirements and organizational constraints of the conceptual design, functions, and experiences. According to the authors, a failure mode is a loss of quality in the

system function. Therefore, this model seeks to analyze the potential failures of the system functions or the improvement of their effects in order to prevent the failure from reaching the customer.
However, Stock (2003) states that the CFMA takes a first step in the right direction by analyzing the product via fulfillment of the functions, but still has a dependence on the component shapes and retains the traditional FMEA language, which has a high degree of subjectivity.
Stock (2003) presents the Elemental Function-Failure Design Method (EFDM), which seeks to connect the concept generation process of conceptual design to the failure analysis. In this model, the designer defines the functional structure and the flow of energy, material, and signal in order to then perform an analysis of the fulfillment of the function. This model does not compare the functions with an existing failure modes knowledge base or something similar. A survey is carried out on these verified failure modes, and also an auxiliary function to minimize or exclude the failure mode is introduced, should it be required.
Some advantages pointed out by the author are the possibility of forming a design team of people without experience to evaluate product reliability with the support of the knowledge base. Another advantage is the possibility of developing a product with good reliability without the need for multiple redesigns due to reliability problems. In addition, it has the advantage that the reliability analysis process may be easier and cheaper.
Among the disadvantages pointed out by the author, the main one is that it requires a large knowledge base for relating the failure modes to the functionality. Another important disadvantage in relation to the FMEA is the loss of both the search for the cause of failure and the consideration of product manufacturing information. This is relevant information needed to evaluate this model because this is crucial information for the product lifecycle.
Next, we will present a proposal of FMEA application that, if initiated during the conceptual design phase and developed through to the detailed design, can also be used to evaluate the product manufacturability. The main characteristic of this proposal is that its application enables the evaluation of compatibilities and interactions between the product systems, subsystems, and components, and their failure modes. This, in turn, allows for analysis of the incidental effect beyond the functional interfaces. This proposal is called Continuous Design FMEA (CDFMEA).

3 METHOD PROPOSED – CONTINUOUS DESIGN FMEA (CDFMEA)

The proposed method consists of using FMEA during the Conceptual Design phase, which will take place along with the Functional Structuring of the product and with the Morphological Matrix. The proposal is based in the traditional FMEA. It utilizes concepts of QFD like design specifications and weight requirements. The proposition begins with the Functional Structuring of the product, where, after it has been unfolded to the level of elementary functions and energy flows, material and signal are defined, and the first stage of FMEA is performed. This FMEA is called Functional FMEA due to evaluate the PRNs in the functional level. The first stage is the study of possible product failures in functional terms. It is important to point out at this point that the product failure concept is either full or partial non-compliance of the function for which the product has been designed, and the objective of the product is the performance of its functions. Therefore, the focus on reliability as a parameter for concept selection becomes more relevant to the quality of the end product. In order to study the failures, a survey of the possible effects they may cause is carried out. This includes an assessment of the severity of each failure, with values presented in Table 1.

Table 1. Severity of functional effects adapted from BEN-DAYA and RAOUF (1996)

Severity	Score
It does not interfere with the function	1-3
It presents a slight loss in function performance	4-5
It presents considerable losses in function performance	6-8
It makes function performance impracticable	9-10

The relative importance of the functions to product performance should also be taken into account. The failure may be related to a basic function of the product, which would render it unusable, or it may be related to a secondary function, which would not have a major impact on performance.

This importance evaluation of functions uses the weight of the design specifications derived from the QFD. This generates a measure that is associated with the severity of non-compliance associated with the function. So, this severity is linked with failure modes of the solution principles that can cause the loss of the function.
It is therefore necessary to establish the use of a relation matrix between the functions and the design specifications. This matrix represents the advantage of possible compromise solutions in the later phases. An example of this is shown in Table 2 and the calculation of relative importance of function is determined by (1).

Table 2. Relation matrix between functions and design specifications

Design Specifications/Functions	Weight of specifications	Function 1	Function 2	...	Function n
Specification 1		X	⊗		
Specification 2					
Functional weight					

$$\textit{Functional weight} = \Sigma P_i \times R \quad (1)$$

Where: P_i – Specification Weight
R – Value of relation determined in the matrix (when it exists, it is 1, otherwise 0).
Completion of these tasks is followed by creation of the morphological matrix. In this phase, the model seeks to reduce the number of combinations to be evaluated, as well as to perform an analysis of the interactions between principles, by means of a previous sorting of the combinations based on reliability criteria.
To achieve this, this paper suggests the application of FMEA only to the critical Solution Principles (PSs) using the definition of criticality as a basis for the functional weight obtained in Table 2. In the application of FMEA, the severity value previously obtained in the functional phase is also used.
Thus, as soon as the morphological matrix is prepared, FMEA is applied (Table 3) in the critical PSs. After mapping the effects and associating the severities to the PSs, the calculation of PRNs is made for each failure mode of the PSs. This calculation is performed according to Eq. (2).

⊗ - there is a relation between specification and function
X - there is no relation between specification and function

Table 3. Solution principle FMEA

PS	Function	Failure Mode	Effects	Sev	Causes	Oc	Control	Detect	PRN
PS_i	Function n	FM_1	Effect 1		Cause 1		Type 1		
		FM_2	Effect 2		Cause 2		Type 2		

$$PRN\ (PS_i) = \Sigma\ [Sev\ (FM_i) * Oc\ (FM_i) * Detec\ (FM_i)\ ] \quad (2)$$

Where: PRN – Priority Risk Number
Sev – Severity of effect (Tab. 1)
Oc – Occurrence (occurrence probability – Tab. 4)
Detec – Likelihood of detecting the failure (Tab. 5)
FM – Failure mode

To determine the PRN for each PS, it is necessary to determine the interdependence of the failure modes associated with each PS. This may be achieved with a matrix (Table 6) that determines whether the relation between the failure modes is (1) independent, occurring without the presence of the other, (2) linked, only occurring when the other is already occurring, or (3) undetermined, when it is not possible to say anything about it as not all failure modes have an explicit relation or are even known (making the detection of interdependence difficult). It is necessary to consider failure modes for a later investigation, and it is important to point out that this stage of FMEA is carried out to determine the main PSs to be used in concept generation for the product.

Table 4. Occurrence rate of failure modes according to probability BEN-DAYA and RAOUF (1996)

Occurrence Probability	Occurrence Likelihood	Score
Remote	Near 0	1
Low	1/20.000 1/10.000	2 3
Moderate	1/2.000 1/1.000 1/200	4 5 6
High	1/100 1/20	7 8
Very High	1/10 1/2	9 10

Table 5. Failure detection rate according to probability of detection BEN-DAYA and RAOUF (1996)

Probability of not detecting the failure	Probability (%) of an individual defect reaching the client	Score
Remote	Near 0-5	1
Low	6-15 16-25	2 3
Moderate	26-35 36-45 46-55	4 5 6
High	56-65 66-75	7 8
Very High	76-85 86-100	9 10

Table 6. Interrelation matrix among failure modes

Failure Modes X Failure Modes	FM_1	FM_2	…	FM_{n+1}
FM_1				
FM_2				

L – Linked failure modes; I – Independent Failure Modes; N – Needs investigation

After having determined the PRNs of the critical PSs, concepts are generated by joining the PSs. Thus, it is necessary to combine different principles to obtain concepts for the solution of design problems. It is then necessary to analyze the influence that each PS will have on the others and on their respective failure modes. This analysis is done by studying the interfaces between the PSs. Thus, it is necessary to check whether interfaces exist and what kinds of interfaces there are between principles within each conception. Next, the type of relation between the PSs is established in order to identify whether there will be mutual interference in performance of the function.

This task can be carried out through a new application of FMEA at the conception level. Assembly, manufacturing, and cost factors must also be considered in the development of solutions for the failure modes. These can reveal impractical concepts at this early phase in the task. Should more serious problems be detected in the FMEA of the generated concepts, interaction may be addressed from this point on and not in the later phases of the design cycle.

Once the concepts have been evaluated in terms of reliability, it is possible to establish that concepts that have the lowest PRNs are the ones most likely to solve the problem. It is necessary, however, to point out other factors that must be evaluated in order for the design team to reach a conclusive definition. Figure 2 shows a representation of the proposed model with emphasis in the tasks presented.

4 CASE STUDY

A case study was used to evaluate and verify the applicability of the proposed model. The chosen product was a precision fertilizer equipment that was composed by several modules. This case study apply the proposed model in the doser module. It was done in a simple way; only one model of fertilizer application equipment was used as an evaluation parameter (Menegatti, 2004). A piece of the functional structure of this equipment was used for this task (Figure 3**)**.

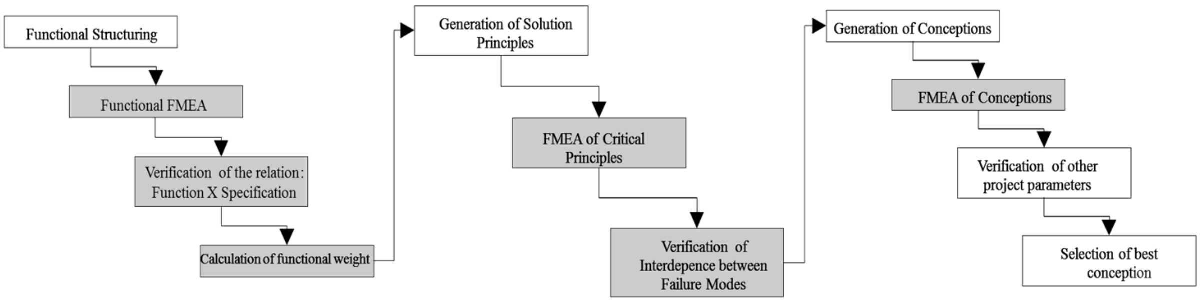

Figure 2. Schematic model of FMEA application in conceptual design

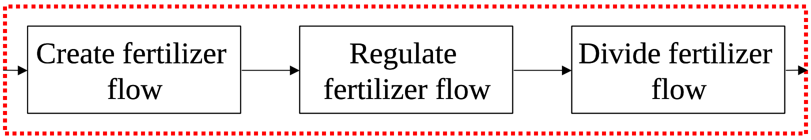

Figure 3. Functional Structure of equipment of application of fertilizer

Based on the presented functions, the functional structure, and the severity degrees shown in Table 1, the function criticality was evaluated as shown in Table 7.

Table 7. Severity description of non-fulfillment of function

Function	Sev	Severity description
Create fertilizer flow	10	Without the creation of the fertilizer flow it becomes impossible to operate the machine.
Regulate fertilizer flow	9	Control of the fertilizer flow is indispensable to the application of fertilizer on the soil. However, an inadequate control will not necessarily cause a total loss of functionality.
Divide fertilizer flow	8	The division of fertilizer flow can cause considerable loss to equipment functionality, but will not necessarily hinder the complete operation.

After this task, an analysis was performed to verify the interrelationship between the design specifications, defined in the informational design, and the functions found in the functional synthesis of the product. The partial list of specifications and their relationship are illustrated in Tables 8 and 9.

Table 8. Partial list of design specifications

Design Specifications	Specifications weight	Target value
Permissible size of sediment particles	5	≤ 6mm of diameter
Conventional manufacturing processes	3	100% of processes
Fertilizer flow rate	3	From 0 to 0,115 kg/s
Mass flow rate coefficient of variation	1	≤ 20%
Fertilizer storage capacity per line of plantation	1	150 kg

Through this matrix, we can see that the functions “create fertilizer flow” and “regulate fertilizer flow” are more important than the function “divide fertilizer flow.” However, since this paper deals with a piece of an equipment design, the function “divide fertilizer flow” will be considered. Otherwise, this function would be discarded from the FMEA analysis. Next, starting with the morphological matrix

(Table 10), we can continue with the FMEA analysis. This analysis will consider the functional severity (Table 1), the occurrence (Table 5), and the facility of detection (Table 6).

The next proposed step is the interdependence analysis. This process is relevant because many failure modes are the consequence of other progressive and undetectable failure modes. Therefore, the execution of this evaluation presented in Table 11 is necessary.
With these results, we can generate the concepts of the product that attend to the possible failure modes shown by the FMEA. The concepts generated are shown in Table 12.

Table 9. Relationship between design specifications X functions

Design Specifications / Functions	Specifications weight	Create fertilizer flow	Regulate fertilizer flow	Divide fertilizer flow
Permissible size of sediment particles	5	⊗	⊗	X
Conventional manufacturing processes	3	X	X	X
Fertilizer flow rate	3	⊗	⊗	⊗
Mass flow rate coefficient of variation	1	⊗	⊗	X
Fertilizer storage capacity per line of plantation	1	⊗	⊗	X
Functional Weight		10	10	3

Table 10. FMEA of fertilizer application equipment for one function

Solution Principles	Function	Failure Modes	Occ	Effects	Sev	Causes	Det	PRN
Dosage by vanes	Create fertilizer flow	Bind	2	do not create fertilizer flow	10	Corrosion	8	160
	Regulate fertilizer flow	Clogging	6	irregular flow	10	Consume	7	420
	Divide fertilizer flow	Corrosion	2	irregular division of flow	3	rocks in the fertilizer	2	12
		break of vanes	4		7	excessive tolerances	8	224
		Consume	2		1	irregular feed flow	2	4
		Irregular rotation	2		4	bad adjustment of equipment	4	32

Table 11. Matrix of interdependence of failure modes

Failure modes	Clogging	corrosion	break of vane	consume	Irregular rotation
Binding	N	N	N	I	N
Clogging		N	I	N	I
Corrosion			N	I	I
break of vane				N	I
Consume					I

Table 12. Product concepts and respective PRNs

Function	Concepts				
	Conception 1	Conception 2	Conception 3	Conception 4	Conception 5
F1 Create fertilizer flow	Dosage by vanes	Screw feeder	Axis with rotating shovels	Diaphragm	Horizontal feeder
F2 Regulate fertilizer flow	Dosage by vanes	Screw feeder	Axis with rotating shovels	Diaphragm	Horizontal feeder

F3 Divide fertilizer flow	Dosage by vanes	Screw feeder	Rectangular divider of flow	Rectangular divider of flow	Rectangular divider of flow
ΣPRN	852	592	1152	1387	932

According to these concepts, it can be seen that it is necessary to make a qualitative analysis of the combined results of the FMEA to each conception. This analysis showed that, in theory, the best concept is that which presented a lower PRN, which is Concept 2 in this case. However, if the results of the interdependence matrix are considered, it can be seen that there are interactions among the failure modes. These interactions must be investigated with more accuracy. If there are some linked failure modes, the calculation of PRN must be changed to another form. In addition, we must consider the fundamental and incidental interactions between solution principles and other aspects, such as the manufacture, assembly, and costs, for example.

5 CONCLUSIONS

Based on the study carried out, some relevant aspects can be identified:
Performing tasks at the beginning of the design that in the past were only carried out in the final phases of development design has become a more frequent practice in recent years. It is believed that this is due to the current practice of multidisciplinary environments and the development of new management philosophies such as knowledge management. This kind of context creates a need for improved design techniques, thus making the design more compact and dynamic. Therefore, applying FMEA (and other techniques) is no longer a revolution, as there is a potential context in terms of research.
The application of the proposed method shows some advantages. These are the design evaluation under the perspective of functional compliance including the establishment of a measure based on the FMEA parameters, the definition of better solution principles under this perspective, the mapping of failure modes interactions and the interrelationships between the function and failure modes.
There are some questions to solve about the method. The applicability in complex systems can be difficult and some interactions between the failure modes are impossible to map.
Regarding the results obtained from this study, it is possible to identify a few points in the model presented for discussion:
The metrics proposed need to be applied in a more integrated manner with other aspects of the product, such as assembly and manufacturing.
The method must also be applied in more case studies to collect more concrete examples of its application before proceeding to an analysis of adjustment needs.
It may be necessary to use statistical methods associated with the proposed metrics, considering the method deals with aspects of reliability.
A case study is necessary to analyze possible influences of the functional structure on the product along with its energy flows, material, and signal in the procedure described in this paper.
Therefore, we believe that through a greater quantity of practical data, the questionable points of this paper will be explained, thus enriching and making the use of FMEA possible in the conceptual design phase.

REFERENCES

Arcidiacono, G.et alli. (2003) Systematic approach to product design using axiomatic design: Application to a diesel locomotive. In: *International Conference on Engineering Design – ICED 03*, 14th - 2003, Estocolmo - SUE. ICED 03 - Proceedings. Estocolmo, Sweden: Design Society, August 2003. CD-ROM.
Ben-daya, M. e Raouf, A (1996). A revised failure mode and effects analysis model. *International Journal of Quality Reliability Management*, n. 1, v. 13, 1996.
Del Frate, L. (2012). Product failure: A life cycle approach. In: *The 4th GCOE International Symposium on "Weaving Science Web beyond particle-matter hierarchy"*. 2012. Sendai: Japan.
Ferrari, F. M et alli (2001). Ferramentas do processo de desenvolvimento do produto como mecanismos potencializadores da gestão do conhecimento. In: *Congresso Brasileiro de Gestão de Desenvolvimento de Produto*, 3°, 2001, Florianópolis - SC. Anais do 3° Congresso Brasileiro de Gestão de Desenvolvimento de Produto. Florianópolis: UFSC, Setembro de 2001. CD-ROM.

Hata, T. et alli. (2000) Representation of Functional Relations among Parts and its Application to Product Failure Reasoning, Int. *CIRP Design Seminar*. 2000. Proc. 393-398 ShpitalniM. Haifa.

Hawkins P.G., Woollons D.J. (1998) Failure modes and effects analysis of complex engineering systems using functional models. Artificial Intelligence in Engineering, 12 (4), 1998, pp. 375-397.

Kmenta, S. et alli. (1999) Advanced failure modes and effects analysis of complex. In: *ASME DESIGN ENGINEERING TECHNICAL CONFERENCES*, DETC99/DFM8939., 1999, Las Vegas, Nevada. Proceedings of the Design Engineering Technical Conferences. Las Vegas, Nevada, USA: ASME, 1999. p. 1 - 9.

Menegatti, F. A. (2004). Desenvolvimento de um Dosador de Fertilizantes Sólidos Modular para Agricultura de Precisão. 2004. 1 v. Dissertação (Mestrado) - Departamento de Engenharia Mecânica, Universidade Federal de Santa Catarina, Florianópolis, 2004.

O'Halloran, B.M. et alli (2011). Early Design Stage Reliability Analysis Using Function-flow Failure Rates. In: *Design, Theory, and Methodology* Washington, D.C., 2011.

Pillay, A. and Wang, J (2003). Modified failure mode and effects analysis using approximate reasoning, *Reliability Engineering and System Safety* 79 (2003), pp. 69–85.

Rausand, M. & Øien, K. (1996) The basic concepts of failure analysis. *Reliability Engineering and System Safety*, 1996.

Sakurada, E.Y. (2001). Techniques of Failure Mode Analyses and its Effects and Failure Tree Analysis in the development and evaluation of products. Post-Graduation Program in Mechanical Engineering, UFSC, 2001. Master's Dissertation

Stamatis, D.H.(2003) - *Failure Mode and Effect Analysis*: FMEA from theory to execution. ASQ Quality Press, Second Edition, Milwaukee, Winsconsin.

Stock, M. E. (2003) Linking component function to component failure for use in conceptual design failure analysis. Presented to the Faculty of the Graduate School of the UNIVERSITY OF MISSOURI-ROLLA. In: Partial Fulfillment of the Requirements for the Degree MASTER OF SCIENCE IN MECHANICAL ENGINEERING, 2003.

Tumer, I. Y. et alli (2003). Requirements for a Failure Mode taxonomy for use in Conceptual Design. In: *International Conference on Engineering Design – ICED 03*, 14th - 2003, Estocolmo - SUE. ICED 03 - Proceedings. Estocolmo, Sweden: Design Society, August 2003. CD-ROM.

Vilakathara, H. (2013). A First time right design methodology for successful development of automotive SoC products. In: Design and Reuse. http://www.design-reuse.com/articles/31805/design-methodology-automotive-soc-products.html , apr, 2013

Weiss, M. P.; Hari, A. (1999). CFMA – An Effective FMEA Tool for Analysis and selection of the Concept for a New Product. In: *ASME DESIGN ENGINEERING TECHNICAL CONFERENCES*, 99., 1999, Las Vegas, Nevada, Eua. 1999 Proceedings of the Design Engineering Technical Conferences and Computers in Engrg Conference. Las Vegas, Nevada, USA: ASME, 1999. v. 1, p. 1 - 14.