Radha Velangi, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 7, Issue 11, November 2017, pp 99-105

RESEARCH ARTICLE OPEN ACCESS

Assessing mechatronic systems' anticipated dependability: current state of the art

Shivaling I Mukanavar[1], Radha Velangi[2]
[1]*Lecturer / Mechanical Dept, Government Polytechnic Belagavi*
[2]*Lecturer / ECE Dept, Government Polytechnic Hubli*

ABSTRACT

Mechatronic system reliability analysis is a relatively new and active area of study. It is addressed whenever dependable, accessible, and secure systems are required. To lower costs and the quantity of prototypes needed for system validation, reliability studies must be carried out earlier in the design phase. After that, the reliability procedure is implemented for the duration of the development cycle. Predictive reliability, experimental reliability, and operational reliability are the three main stages of this procedure. This article's primary goal is to provide a sort of overview of the numerous studies that allow for a notable understanding of predictive dependability. The areas of weakness are emphasized. For upcoming reliability studies and academic research to develop new techniques and tools, it is crucial to provide an overview of all the quantitative and qualitative methodologies related to modelling and assessing the prediction of dependability. The mechatronic system is dynamic, adaptable, and interactive, making it a hybrid system. These criteria must be considered in the dependability prediction modelling that is done. Numerous approaches have been produced in this line of inquiry. This study will provide an analytical sketch of the techniques in this regard.

Keywords: Functional analysis; failure; dysfunctional analysis; mechatronic; reliability engineering; modeling qualitative analysis; stochastic model; Bayesian Network; Petri nets; Dynamic; Hybrid; Interactive; Reconfigurable; FMEA, redundancy.

Date of Submission: 01-11-2017 Date of acceptance: 10-11-2017

I. INTRODUCTION

One real obstacle for upcoming products is the dependability of mechatronic systems. However, as a field, it is still evolving, driven by market demands and technological advancements. The primary characteristic of the mechatronic method is coupling, which occurs between several scientific domains and technologies. The risk of malfunction is increased by this increase in complexity at all levels. The designers have access to a wide range of techniques and tools that help them master reliability, but these are frequently too specialized and advanced for systematic use and on an industrial scale within a mechatronic framework.

The fundamental tenet of mechatronics is to maximize these couplings to provide improved technical and economic performance; hence, sources of value are added. An expansion in the complexity of the systems, their control, and the design and manufacturing processes is an inevitable consequence of increasing coupling levels. It would be beneficial to briefly define the term "mechatronics" before discussing "mechatronic reliability," which serves as the focus of this study. "Mechatronics" is defined as a "approach aiming at the synergistic integration of mechanics, electronics, control theory, and computer science within product design and manufacturing, in order to improve and/or optimize its functionality" in the French standard NF E 01-010 [1].

Elsevier [2] defines mechatronics as the synergistic fusion of engineering, electronic control, mechanical precision, and systems related to product design and manufacturing procedures. It has to do with designing systems, tools, and goods with the goal of striking the best possible balance between the fundamental mechanical structure and overall control. This paper's goal is to facilitate the quick publication of topical papers that highlight useful advancements in mechatronics. It will draw readers from a variety of academic and industry research fields and cover a broad range of application areas, such as computer integration, manufacturing techniques, instrumentation, consumer product design, and process and device control. Aspects of innovative mechatronics design philosophy that highlight the advantages of integrating functionality with embedded microprocessor control first will be given special attention. The intricacy of mechatronic systems is a significant obstacle in the field of predicted dependability; in this instance, numerous studies have been conducted to address this issue successfully while adhering to norm 2626.

The design phase of the mechatronics approach is modelled by the cycle in V, and the development model based on the cycle in V establishes the locations of the various stages of development, starting with the specification and ending with validation [3]:

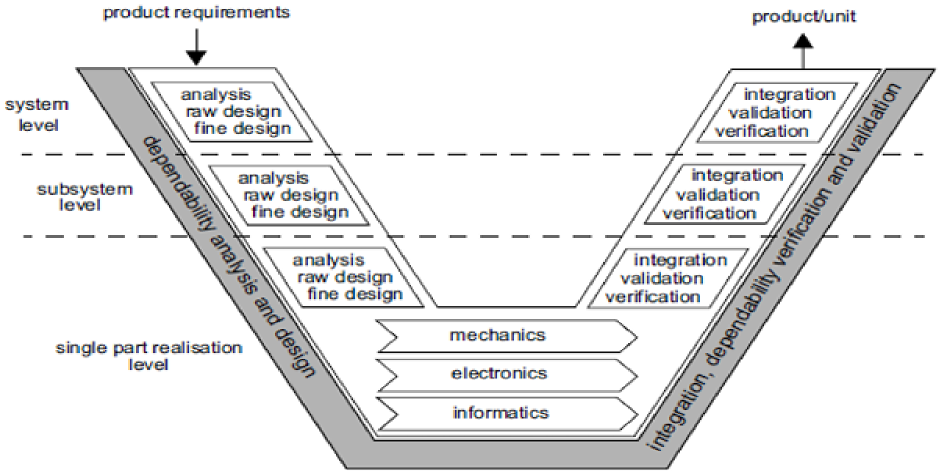


Figure No. 1 - Integration of dependability methodology in the V-model for the development of mechatronic units.

Therefore, it is vital to define "reliability," which is the capacity of an entity to carry out the necessary tasks under specific conditions for a specified amount of time. The following steps of the mechatronic technique have been used to tackle this concept, per multiple studies [8]:

- This phase involves examining dependability from the start of the project using quantitative methods (fault tree analysis, event trees, etc.) and qualitative methods (failure types and effect assessments, etc.) while integrating the various data sets. Petri Net can be used to model the reliability of complicated systems. Predictive reliability enables us to make the best decisions in the design industry.
- This stage starts as soon as the first prototypes and a suitably advanced stage of product development are achieved. It is feasible to conduct robust testing, sometimes known as aggravation tests, to identify design flaws and margins. To determine reliability, several tests may be carried out after the product is mature (has adequate margins). Screening tests are used during production to eliminate minor flaws (weak component, drift process, etc.).
- After the product is operational, reliability is estimated using the return of experience (or "REX") data. It is used in the initial stages and aids in fixing design and manufacturing/production flaws.

II. PROBABILITY

Aspects that are hybrid, dynamic, interactive, and adaptable define mechatronic systems [12]: Systems that explicitly and concurrently involve continuous phenomena and discrete occurrences are known as hybrid systems [30].

A variety of functional interactions influencing its constituent parts define dynamic systems. The system will be regarded as static if these relationships don't change as it performs its different functions.

However, the system will be considered dynamic if these relationships alter while they are operating. The presence of functional and/or physical interactions among a system's constituent parts characterizes its interactive nature. Lastly, systems that can alter their internal structures to guarantee the function is realized are known as reconfigurable systems. The summary that follows includes comparatively in-depth research that is extremely relevant to the topic of mechatronics reliability.

III. EXTRACTING CRITICAL SCENARIOS FROM PETRI NETS

Sarhane Khalfaoui's works [4], [5] were created in cooperation with the CNRS Laboratory for Analysis and Architecture of Systems and PSE Citroën, a company that specializes in the field of mechatronic system dependability, specifically developing a methodology for estimating these systems' reliability. Khalfaoui has created a research methodology that examines the scenarios that are questioned in connection with evaluating the functional safety of automobile mechatronic systems. He tackled mathematical modelling using Petri networks and a few differential equations in his first published paper [5], "Extraction of the scenarios critical from a Petri networks model using linear logic."

This decision was supported by the model's widespread application in research pertaining to the safe operation of dynamic systems as well as in the modelling of discrete event systems. In order to identify some critical scenarios—which are the result of one or a series of failures that put the system in a state of blockage in the absence of repair—a qualitative analysis is conducted using this model to identify the scenarios leading to the dysfunctional event through a causality analysis supported by linear logic and backward reasoning, beginning with the default state and ending with the normal operative state. The electromechanical system and the system controlling reservoirs are the two systems to which this technique has been applied. Given the mixed nature of mechanical systems, the PN Stochastic Determinist is a very suitable model for both discrete and continuous aspects of these systems.

typical state in the backward reasoning, the effect of the discrete part on the suggested method's algorithm, and the absence of the quantitative analysis portion. The variety of possibilities that could result in unpleasant conditions is one of this method's drawbacks. Additionally, by using graphs of proof in a linear logic that permits the handling of partial orders, scenarios are extracted straight from a template PN of the system, circumventing the combinatorial explosion issue and avoiding the graph of accessibility.
If not, the drawback of this strategy is that it only uses the template's discrete feature. In terms of the continuous dynamics, numerous inconsistent possibilities are produced. Furthermore, the scenarios that are produced are not minimum, and the sequence in which the events occur is not taken into consideration.

Following Khalfaoui's footsteps, Malika Mejdouli [6] adopted the methodology "evaluation of the likelihood of occurrence by an approach based on linear logic and the Petri network of Predicates Transitions Differential Stochastic, as well as Furthermore, she has created an updated algorithm that removes conflicting circumstances related to the system's ongoing dynamics. Moreover, this algorithm has been automated (this step was suggested in the viewpoint produced by Khalfaoui). It has created a Java tool called ESA Petri Net (Extraction & Scenarios Analyser by Petri Net model) that enables the extraction of crucial scenarios that result in the undesirable state from a temporal Petri net model and the use of calculators to verify certain system properties. Lastly, the aircraft control system's landing gear is used to test and apply this tool.

Malika Medjoudli's method better described the situation and its various attributes as the "minimality" by accounting for the continuous aspect through temporal abstractions as needed. However, there are undoubtedly additional ways to increase the "minimality" of the algorithms and situations that are created.

IV. THE ESTIMATION OF RELIABILITY BY QUALITATIVE AND QUANTITATIVE MODELING

A. Demri [9], [10] states that two methods—a qualitative approach and a quantitative approach—were used to estimate reliability. The functional and dysfunctional analyses form the basis of this study's qualitative analysis. By using the Structured Analysis and Design Technique S.A.D.T. or S.A. in real time SART (which lacks SADT's dynamic component), the functional one enables an arborescent decomposition of the system. It can even create a Petri Net correspondence. The FMEA and AEEL methodologies for failure define dysfunctional analysis, and both analyses will create a PN model. Creating lists of potential component failure modes from descriptions of each system component and attempting to deduce how those failures might affect the system constitute the fundamental steps of an FMEA.

Laws pertaining to functional transitions applied: The physical system must be represented using equations and partial derivatives that take into consideration the random variables to determine the time associated with functional transitions. The continuous variables of the system's energy component can evolve thanks to these equations. Using the laws pertaining to dysfunctional transitions:

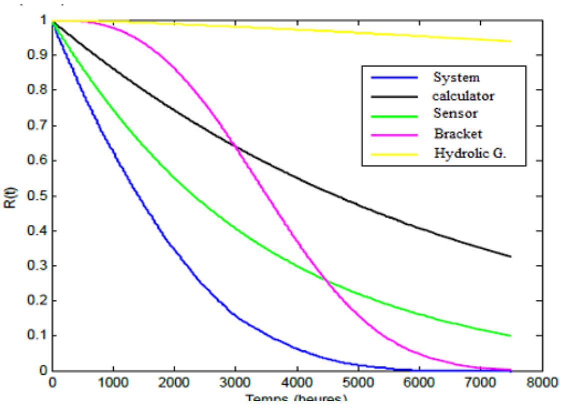


Figure No. 2 - Reliability of the ABS system and its components.

The necessity to divide the research of mechanical reliability systems into two phases—qualitative analysis and quantitative analysis—led to the development of the A. DEMRI [9]. Moncelet has prepared this strategy [21]. The primary challenge in qualitative analysis is the combinatorial proliferation of the graph's states, while the discretization of the continuous section causes prohibitive simulation in the quantitative analysis.

V. THE ESTIMATION OF RELIABILITY BY QUALITATIVE AND QUANTITATIVE MODELING WITH THE RETURN OF EXPERIENCE

Based on a functional model that provides the time of operation and a dysfunctional model that provides the moments of failure, stochastic determination was made. The ABS mechatronic system has been subjected to the technique. As an aside, each component's data collections should be present. Reliability data, often known as return of experiences, or "REX," is readily available. One frequently makes use of well-known databases or, better yet, information from the component manufacturers whenever feasible. H. Belhadaoui's work also establishes these collections.[20].

Additionally, we may model the system's architecture and even simulate its functioning using databases of component reliability. Because certain components are absent from the available data sets, this approach produces better findings in the field of electronics but worse results in the field of mechanics.

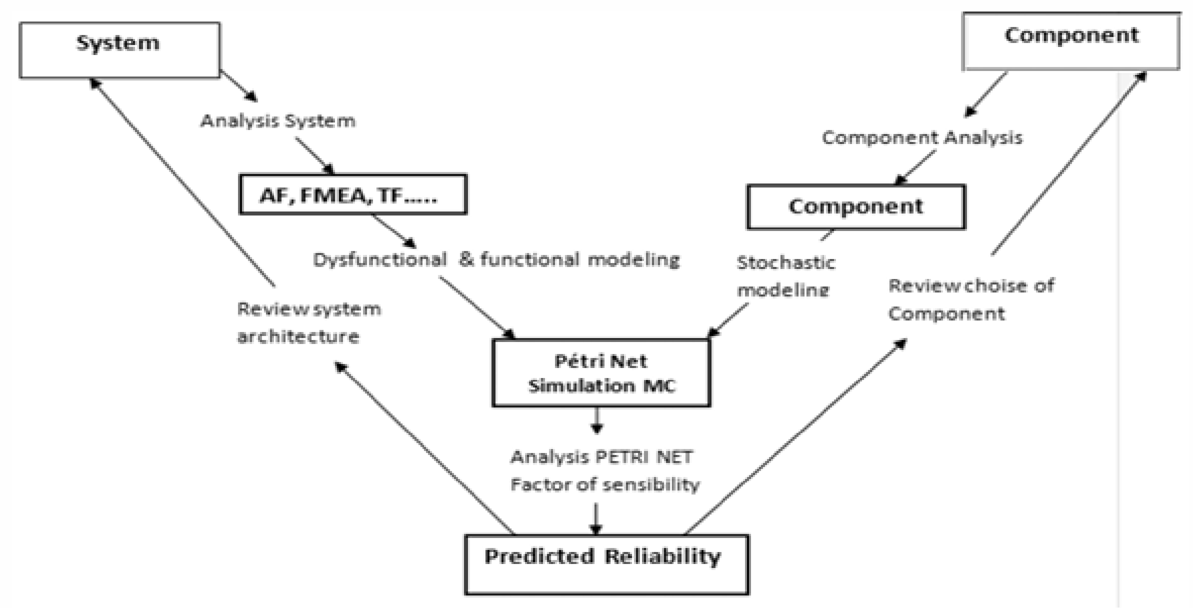
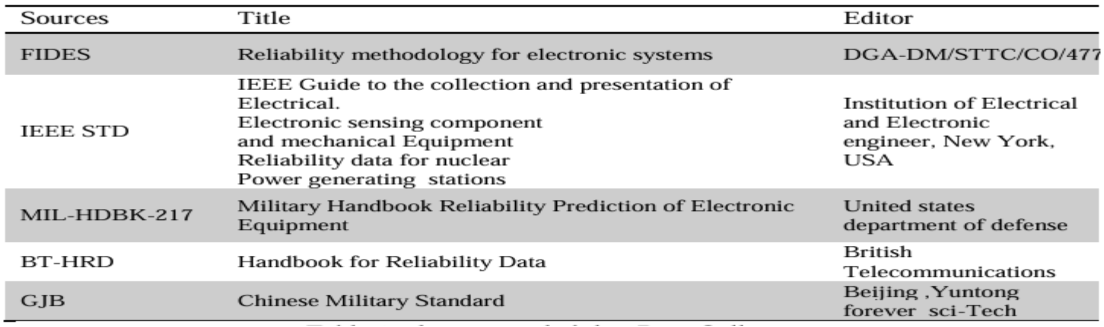


Figure No. 3 - Evaluation Methodology predicted reliability of Mechatronic systems

This developed methodology makes it possible to: model and simulate both functional and dysfunctional behavior of systems; estimate reliability (convenient interval and punctual estimator) through simulation; and perform sensitivity analysis to ascertain how each component contributes to system reliability.

For mechanical systems, J. Gäng [25] suggests an additional approach called the "HOLISTIC RELIABILITY METHOD," which includes a qualitative analysis, quantitative modelling, data collection reliability, and additional procedures like accounting for the functional failure behaviour model. The issue with quantitative modelling is that the impact is invisible.

An illustration of the indexed references for electronic components can be found in the tables below [3]:



Sources	Title	Editor
FIDES	Reliability methodology for electronic systems	DGA-DM/STTC/CO/47
IEEE STD	IEEE Guide to the collection and presentation of Electrical. Electronic sensing component and mechanical Equipment Reliability data for nuclear Power generating stations	Institution of Electrical and Electronic engineer, New York, USA
MIL-HDBK-217	Military Handbook Reliability Prediction of Electronic Equipment	United states department of defense
BT-HRD	Handbook for Reliability Data	British Telecommunications
GJB	Chinese Military Standard	Beijing ,Yuntong forever sci-Tech

Table 1: electronic reliability Data Collection

VI. RELIABILITY ESTIMATION BY TAKING INTO ACCOUNT THE INTERACTIONS MULTI DOMAIN

However, other features of mechatronic systems, such their hybridity, reconfigurability, and interactivity, have been overlooked in earlier research. These elements are crucial for assessing these systems' dependability. In this instance, N. Hammouda [11] presents the idea of organic analysis, which enables specifying the system's architecture with all its bodies, components, and interfaces in order to satisfy the required technical functions. The following are the primary phases involved in creating organic architecture:

By organizing into organs, the matrix functions/components are created so that the functional interactions are listed at both the system and component levels.

After a morphological investigation, the interconnections between the different constituent organs of a main architecture are determined by an analysis of interactions between organs.
An illustration of organic architecture that makes it possible to see where the different parts or organs are located as well as how they are connected. The following is the suggested approach [12]:

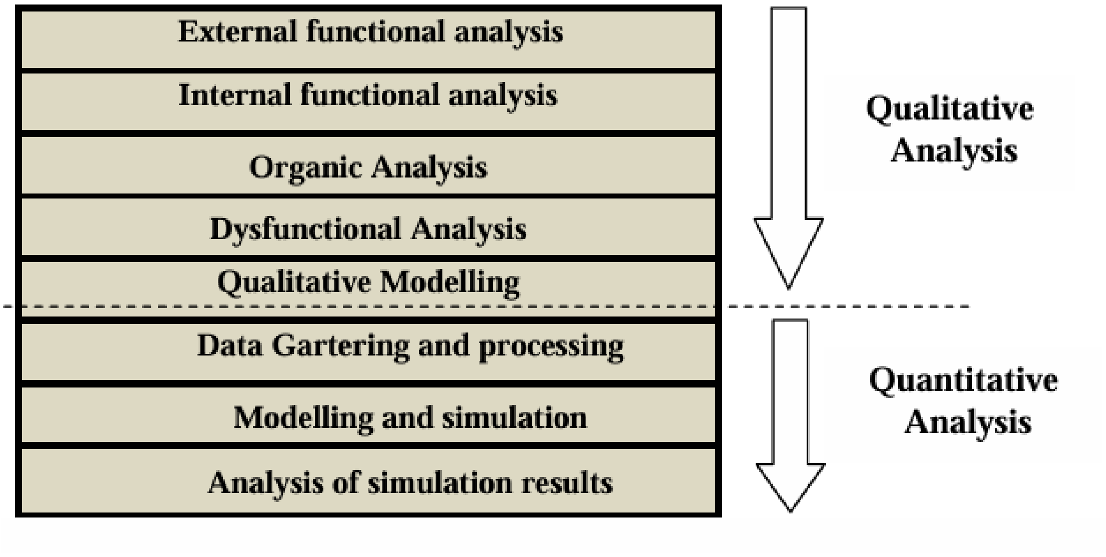


Figure 4: Estimation Approach of mechatronic reliability

The two hybrid/dynamic aspects are now thoroughly discussed. Therefore, N. HAMMOUDA and G. HABCHI [12] added organic analysis and functional analysis to the interactive aspect before injecting additional transitions that depict the interactions between the multi-domains into the PN, which was already created for a system (dynamic hybrid). They select the interaction coil/bearing as the interface between the mechanical and electric domains as an implementation of this proposal. This suggestion improved the estimation of the "intelligent actuator" system's dependability. However, the process they used to identify this relationship and demonstrate this new tool is still not accurate. One could view this inaccuracy as a chance to carry out additional research.
In the same vein, J. Gäng [5] suggests a technique called situation-based qualitative modelling and

analysis (SQMA) that depicts information exchange, physical variables like material flow or power transfer between components, and human interventions as follows:

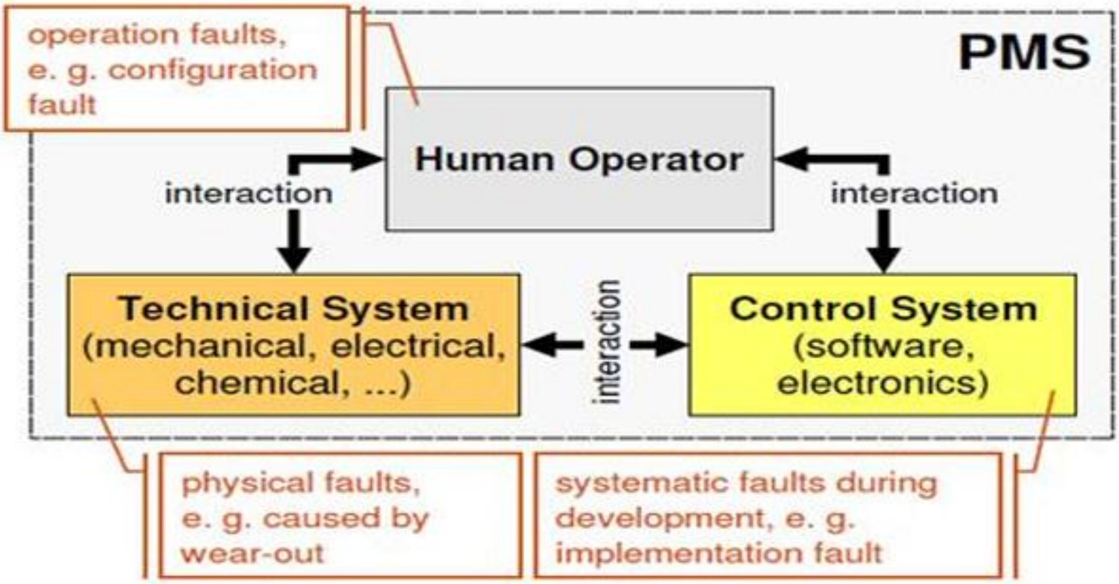


Figure No.5 - Structure of a computer-controlled mechatronic system

The SQMA tool offers the ability to identify the essential circumstances in each component; concrete examples of mechatronic systems can be used to study and analyze this approach.

VII. CONCLUSION

This article has discussed many techniques and strategies for evaluating a system's dependability. These have led to a deeper comprehension of the dynamic, interactive, hybrid, and reconfigurable features of mechatronic systems. We have observed that the results are lacking in several areas, though, which leaves the door open for a potential expansion of our study. Finally, we would want to make clear that based on the findings that were presented: One useful tool that aids in better defining a maintenance strategy is the evaluation of a system's reliability. We can also address additional aspects, such as the system's complexity resulting from the integration of several technologies (mechanical and electrical). Climate: dampness, The temperature, Electricity: voltage, current, ON-OFF cycles, etc. Mechanics: vibrations, chocs mechanics, torsion/flexion, etc. Additional product-specific factors include radiation, magnetic/electrical fields, and electrostatic discharges, as is the case with electronic items.

Designing mechatronic systems with a high degree of technological integration necessitates integrating various domains (mechanical, electrical, software, and automatic) from the outset. This leads to a complicated process that compromises the system's conceptual reliability. Similarly, in our other publication, we provide a new tool to assess these connections, as well as the software/hardware interactions in subsequent research. Regarding the reconfigurable component, research on estimating dependability in reconfigurable systems is still in its infancy. Our research on the same topic, particularly regarding a reconfigurable mechatronic system, has been fruitless. Since the mechatronic sector is still in its infancy, gathering data on experience is still a significant research issue. For this reason, we also suggest developing a new, relevant database for mechatronic components. Lastly, it is crucial for the advancement of tools and techniques in this field to consider the uncertainty involved in assessing projected reliability.

REFERENCE

[1]. La norme française AFNOR de la mécatronique: NF E 01-010
[2]. Key Factors of Dependability of Mechatronic Units - Mechatronic Dependability - Hans-Dieter Kochs Institute of Information Technology University of Duisburg-Essen, Germany.
[3]. S.Khalfaoui, E. Guilhem, H. Demmou, N. Rivières, “ Extraction de scénarios critiques à partir d’un modèle RdP à l’aide de la logiqueLinéaire ”, MSR 2001 Modélisation des systèmes réactifs, 17-19 Octobre2001, Toulouse, France p. 409-424. Rapport LAAS No01126

[4]. S. Khalfaoui, E. Guilhem, H. Demmou, R. Valette, “Modeling critical mechatronic systems with Petri Nets and feared scenarios derivation ECM2S5 5th Workshop on Electronics, Control, Modeling, Measurement and Signals, 30-31 May, 1er Juin, 2001, Toulouse, France p. 55-59. Rapport LAAS No01027

[5]. Malika MEDJOUDJI 2006: Thèse de doctorat Contribution à l’analyse des systèmes pilotés par calculateurs: Extraction de scénarios redoutés et vérification de contraintes temporelles.

[6]. Mihalache, A., Guerin, F., Barreau, M., Todoskoff, A., et Dumon,B. (2004). Reliability assessment of mechatronic systems: operating field data analysis. In IEEE International Conference on Industrial Technology, Hammamet, Tunisia.

[7]. Mihalache A, Guerin F, Barreau M, Todoskoff A, Dumon B (2006) Reliability analysis of mechatronic systems using censored data and Petri nets: application on an antilock brake system (ABS). In: IEEE international conference.

[8]. Amel Demri 2009. Thèse doctorale: Contribution à l'évaluation de la fiabilité d'un système mécatronique par modélisation fonctionnelle et dysfonctionnelle ; thèse de doctorat, Université d'Angers,

[9]. A.Demri, A. Charki, F. Gu_erin, and H. Christofol. Mod_elisation d'un système complexe grace aux reseau de petri et a l'integration de la methode phi2. CFM,2009

[10]. N. Hammouda et al. 2013: Mise en œuvre d’une méthodologie d’évaluation de la fiabilité pour les systèmes mécatroniques. Aubry,

[11]. N.Hammouda, et al. fiabilité des systèmes mécatroniques en utilisant la modelisation et la simulation. Novembre 2014.

[12]. N.Hammouda,et al. Implementation of a methodology for evaluation of the reliability of mechtronic systems. Mecatronics, 2014 10th France-Japan/ 8th Europe-Asia Congress.

[13]. Genia Babykina, Anne Barros, Nicolae Brinzei, Gilles Deleuze, Benote De Saporta, Fran_cois Dufour, Yves Langeron, Huilong Zhang. Rapport final du projet APPRODYN: APPOches de la fiabilitie DYNamique pour mod_eliser des systemes critiques Jean-Fran_cois

[14]. Remi Larond, Fiabilité et durabilité d'un système complexe dédie aux énergies renouvelables Application a un système photovoltaïque.

[15]. Probabilistic error propagation model for mechatronic systems Andrey Morozov, Klaus Janschek Institute of Automation, Technische Universität Dresden, 01062 Dresden, Germany

[16]. Sierla S, Irem T, Papakonstantinou N, Koskinen K, Jensen D 2012) Early integration of safety to the mechatronic system design process by the functional failure identification and propagation framework. mechatronic

[17]. Qualitative and quantitative approaches to analyse reliability of a mechatronic system: a case Rajiv Kumar Sharma • Pooja Sharma.

[18]. PEREZ CASTAÑEDA G.A., Évaluation par simulation de la sûreté de fonctionnement de systèmes en contexte dynamique hybride, Thèse dedoctorat 30 mars 2009.

[19]. H.Belhadaoui, C.Cassier, O.Malassé, J.F. Aubry, ‘Outil d’aide à la conception des systèmes mécatroniques’. Qualita-Tanger Maroc, Mars2007

[20]. G. Moncelet. Application des Reseaux de Petri a l'evaluation de la surete de fonctionnement des systémes mécatroniques du monde automobile. Automatique et informatique industriels, Universit_e Paul Sabatier de Toulouse, octobre 1998.