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A critical review of Design for Reliability - A bibliometric analysis and identification of research opportunities

Lucas Paganin^{a*}, Milton Borsato^a

^a*Graduate School of Mechanical Engineering and Materials, Federal University of Technology – Paraná, Av. Sete de Setembro, 3165, Curitiba (PR), 80230-901, Brazil*

Abstract

It is fundamental to adopt a Design for Reliability (DfR) approach at the stage of new product development in order to guarantee the reliability of an item at all stages of its life cycle. The amount of publications about DfR is not very extensive and it is somewhat dispersed. Thus, the main objective of this article is to collect and perform an analysis of the most recent literature. Fifty publications were analysed with the purpose of identifying the theoretical foundations regarding this topic. Moreover, the main applications, challenges and limitations of DfR were identified aiming the direction for future research.

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1. Introduction

In the last decades, the increasing competitiveness, the design and development of complex products and processes and the relevance given to consumer satisfaction have made studies on product reliability more prominent. According to [1], reliability can be defined as “the probability that a component, device, system or process will operate without failures for a given period if correctly used in a previously specified environment”. The lack of reliability of a product can cause a number of undesirable consequences, such as safety, competitiveness, costs of maintenance and repair and brand reputation issues. Thus, the reliability of a product is closely associated with the number of failures that it will present in a given time interval.

* Corresponding author. Tel.: +55-41-98464-7669.

E-mail address: lucasbzip@gmail.com

According to [2], reliability should be considered at the initial stages and during the entire product development process. The implementation of Design for Reliability (DfR) will help to identify problems associated with prototyping, thereby reducing life cycle cost, field failure rate and product time to market. To accomplish these objectives, activities focused on reliability and quality must be implemented in the product development cycle. Thus, achieving repeatability, stability, and maturity in the product development process at the testing stages is required as a demonstration of reliability.

At the initial stages of product design, several factors that can affect reliability should be considered. Nevertheless, such factors have a significant complexity, which makes them difficult to assess according to their weights and intensity for the reliability prediction. In other words, several uncertainties exist at the initial stages of the design process, thus making reliability estimating more difficult. Therefore, traditional reliability forecasting models may not be suitable for products involving a large number of uncertainties, particularly in the early stages of design [3].

In order to apply Design for Reliability (DfR) throughout a product development cycle, [4] states that the attributes of data collection for analysis need to be clarified in the first instance. Such data sources can be:

- Lessons learned from the field or tests;
- Data obtained from sensors regarding the stress of the product in the field or in test;
- Monitoring the progress of projects and activities;
- Questionnaire and consumer survey data;
- Knowledge of specifications, articles or training; and
- Benchmarking of specifications and requirements.

Taking into account the importance that the reliability of products has received in recent years, the advantages of adopting DfR in the early stages of product development and the scarcity of publications in this area, it is expected that this subject will become more relevant in the forthcoming years. Notably, the DfR research field is in development. Although there are several articles available on the most varied applications, few of these publications reflect what is known about DfR as a whole. In addition, since DfR should be implemented at the initial stages of the development of any product, several mathematical techniques and models appear as a way of modeling and predicting the reliability of what is being created. Some of the applications range from the improvement in the vehicle transmission system [5] to LED (Light-emitting Diode) lifetime [6] and virtual prototyping [7]. There are also investigative and theoretical publications, such as the ones from [8] and [9], that perform a mathematical analysis for DfR implementation.

In light of this dispersion of DfR studies, this article has as main goal to collect and review the literature on the subject in the last five years (2011-2016), seeking to identify the theoretical bases of DfR and the research opportunities about this subject. In order to achieve these objectives, a critical review of 50 relevant articles was performed. The selection and presentation of the details of this article sample are presented in section 2. The results obtained from the analysis of this sample are examined in two stages. Firstly, the theoretical foundations of DfR are discussed in order to obtain a more consolidated view of this area of research in section 3. This includes a brief definition of the terms, an evaluation of the adopted methods and examples of DfR applications. Then, the opportunities for future research are detailed in section 4. As final steps, the conclusion and references are presented.

2. Research Methodology

The literature on Design for Reliability contains a limited number of theoretical publications that demonstrates the main fundamentals of DfR. From the existing publications, the different approaches are mainly linked to: theoretical / investigative [2, 6, 10-13], case studies [1, 14-18], mathematical modeling [8, 9, 19-23], data analysis to predict the reliability of a given product [4, 15], other methods to increase the reliability of a determined product [3, 24-27]. However, only a scarce literature refers to the theoretical foundations of DfR, which would serve as a practical and a generalized guide for its implementation at any company, regardless of the nature of the product to be designed. In this section, a summary of the selection criteria adopted for the choice of the article sample, its characteristics and the adopted revision process are presented.

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