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Failure Classification and Analysis for Technical Products

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Abstract

The paper presents an approach to implement a failure classification and associated analyses for production ramp-up. The structural design of the failure classification is described in terms of a faceted classification by design principles to meet the requirements for the indexing of failure cases and the evaluation of specific failure facets. The structural design of the classification is followed by the design of the content of individual failure facets. The failure facets and their contents are used in the analysis. In this paper, the similarity search and the failure priority analysis are developed as functions, as they are particularly relevant in the ramp-up situation. Conceptual model examinations and case studies are carried out for validation.

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Keywords: continuous improvement, failure management, failure classification

1. Introduction

The presence of the internet of things and services in the factory respectively the digitalization in industry, concerning their products and services is summarized in Germany under the term "Industrie 4.0" [1]. Machines, storage systems and the production facilities will work together in a network as cyber-physical systems (CPS). Real-time systems, the vertical and horizontal integration and the emergence of new business models are some keywords [2].

Important components of this development are sensors as a precondition to realize the promises made under the term "Industrie 4.0". Sensors multiply and simplify the possibilities of data collection. The structure of crosslinked sensors is already part of a new research group. The sensor term is defined widely spread in this context. Sensors include, for example, social media sensors to register the customer comments on defect products. This kind of data collection and the consequent possibilities of data processing help especially in the failure detection and handling. Smartphones, tablets, or other wearables like smartglasses are introduced into the smart factory. As a main application, failure handling is mentioned.

Beside the developments in the industry 4.0 manufacturing companies are in a difficult situation: in the automotive industry and many other industries, technological change leads to a shortening of life cycles and an increasing number of variants through the customization of products. This situation is a major challenge for both ramp-up and failure management. Common strategies try to reduce the complexity. However, the failure modes are highly heterogeneous and the causes are divers. For instance, failures in ramp-up are caused due to issues in engineering, manufacturing and assembly, inadequate maintenance of machines and equipment as well as hardware, software, and operator failures [3].

The following paper provides an approach for the classification and analysis of failures in technical products with a focus on the ramp-up situation. After a detailed problem statement (chapter 2) the literature review is shown and requirements are derived. Methodological aspects are presented afterwards (chapter 4). Chapter 5 introduces the failure classification on which the failure analysis is set up for

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the ramp-up situation. The classification and the analysis are examined in a practical entrepreneurial context which is shown in chapter 7. Finally chapter 8 provides a brief summary and conclusion.

2. Detailed problem statement

The long-term benefit of careful failure and root cause analysis is often not sufficiently recognized due to short-term production targets. An industry study points out that a rigorous analysis of the causes is very rare even in the case of reoccurring failures. The reasons for this can be found in the existing time and cost pressures. High costs for a cause analysis are facing productivity rates or even a production stop. High reject rates are often accepted, although structured failure analysis would prevent future failures and thus could reduce costs [4].

The problem is that manufacturing companies have insufficient structures to realize learning effects from their own failures to improve their processes. This includes in particular the ramp-up process in which the product planning is realized in physical products the first time. In one study, only 22 of 108 companies (20%) are able to reflect their occurring failures correctly. As a result, there is the need for improving the quality of failure detection and classification. After this, improvements can be derived from on a valid failure analysis [5].

Further problems are the failure structure and the failure content description. In many companies, data collection and thus the failure detection is separated into departments (e. g.: in development, in production, in sales departments) or separated due to specific local factors. Moreover, the data structure is heterogeneous and often insufficient for analyzes. The lack of integration of the (partially heterogeneous) data structures in failure management processes is a potential that may arise from the data networking.

This is a contrast to the aforementioned potential of sensors for data collection. The existing data has to be used for the failure description and classification. Failure management can significantly be improved by using this potential. However, it is necessary to collect the right data and to extract the correct data from the plurality of the total data recorded. The typical project approaches like Knowledge Discovery in Databases (KDD) which includes data mining techniques provides solutions. In this approach 75-85% of the total effort are not spend for the analysis, but in steps as the data selection, data preprocessing and data transformation [6,7]. For failure management, which is not in a very crucial task in the company, the use of such project approaches with the necessary human support (expertise) are impractical to answer specific questions in ramp-up.

Fully automated analysis, are established in failure management only sporadically so far. Specific analysis functions, such as supporting the ramp-up process as the critical and most fault-prone phase of production, are not known yet.

3. Literature review and derivation of requirements

A brief literature review in the field of failure management and classification has shown that most of the concepts have not been developed beyond a theoretical prototype and have only found limited or no application in practice [8]. In daily business, the concept often fails due to a not uniform failure recording or description [9]. Regarding this, the precise failure classification is the central element of the overall failure handling process. Due to this lack of clarity, most existing approaches that rely on a uniform classification of failures do not solve the mentioned problems [8].

Concerning this matter, the literature does only enlarge sporadically upon an explicit drafting of failure descriptions. Approaches that, based on a specific example, try to record failures sortable and retrospectively analyzable and try to avoid both, synonyms (comparable situations are described with different terms) and homonyms (different situations are described by the same terminology), are indeed presented, but often do not meet the standard to be transferable to products of other industries.

In preparation of this paper, the authors conducted expert interviews to find requirements in addition to the requirements mentioned in the literature. Those requirements lead to a better understanding what a failure classification and analysis for technical products has to fulfil.

The identified requirements are already presented in further work [8]. In total there are five different categories of requirements: necessity of tasks, responsibilities and competencies (1), possibility for the implementation in existing failure elimination processes (2), easy access for analysis (3), determination of design rules for the classification system (4) and the detailed description for failures, causes and measures of technical products (5).

4. Methodology

Based on the existing scientific approaches (chapter 3) and the expert interviews, the explanatory model shown in Figure 1 is derived. The model presents three core processes, the development, the production and the field support of a manufacturing company. Various failures may occur in all areas. These failures should be handled with a structured failure elimination process [10]. In addition, it is necessary for the company to observe the entire nonconformities. Failures that are caused for example in the development phase become visible in ramp-up the phase or in the field. Therefore there is the need to look at all failures happening across the companies' processes. The observation of the failure events is necessary to detect them and find the right priorities on time and to limit the failures' impact early.

For the elimination of failures as well as for the analysis a system is necessary that fulfills all mentioned requirements and functions. The insights gained must then be transferred to the respective stage of the process, so that actions can be taken there. Within the system, the failures recorded about the failure sensors need to be captured structured. Without a structured recording no meaningful analysis is possible. Failure classification and analysis are sub-elements of the