Enabling agility in product development through an adaptive engineering change management

Günther Schuh\textsuperscript{a}, Thomas Gartz\textsuperscript{a}, Samuel Soucy-Bouchard\textsuperscript{a}, Felix Basse\textsuperscript{a,}\textsuperscript{*}

\textsuperscript{a}Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Steinbachstraße 19, 52074 Aachen, Germany
\textsuperscript{b}Université de Sherbrooke, 2500 Boulevard de l’Université, Sherbrooke, QC J1K 2R1, Canada

* Corresponding author. Tel.: +49-241-8028674; fax: +49-241-8022293. E-mail address: F.Basse@wzl.rwth-aachen.de

Abstract

Agile development processes have recently regularly been named as key to the development of novel physical products. Coming from the software industry, these processes pursue the target of limiting both time-to-market and resources associated with the realisation of innovative products. In the case of physical products, agile development in the form of highly iterative prototyping is furthermore employed for assuring a stable ramp-up phase. The goal of this paper is the creation of an adaptive engineering change management (ECM) for rapid engineering changes which are identified as central enablers for the agile product development of physical products.

Due to a lack of in-depth studies in this field, an agile development project in a manufacturing company has been investigated. The findings of the case study are based on action research. Challenges and requirements faced by the case company have been identified in workshops and interviews. A broad study of closely related literature improved the understanding and helped in the generation of a framework for an adaptive ECM.

The investigations led to an approach that employs a step-wise product development process with different stages of maturity. Hereby, the shift of requirements in the course of the agile development project as observed in the case study is taken into account. The ECM is continuously adapted along the different stages of maturity of the agile product development to cope with this shift of requirements. It is illustrated that the adaptive ECM is reflected in three layers: responsive means of communication, a responsive design of engineering change processes and roles, and consistent data structures. Examples for the specific design of these layers are presented.

The result of the work is thus a framework for an adaptive ECM that meets the specific requirements of agile product development for physical products.

Keywords: Agile development and ramp-up; Product development processes; Engineering change management

1. Introduction

The regular introduction of innovative products is a major success factor for manufacturing companies in a market characterised by shortening product life cycles and increasing customer requirements [1,2]. This makes the ability of manufacturing companies to develop products efficiently even more central than before [3,4]. Performance measures of this ability are above all a short time-to-market and a limited amount of resources needed for the innovation process.

Since the Agile Manifesto was presented in 2001, agile development processes, such as Scrum, have prevailed over phased processes in the software industry. Agile development is a learning-oriented approach [5]. It is characterised by an early and iterative realisation of fully-tested software increments. This is carried out by small development teams that are given a high degree of creative freedom [6]. Development teams learn from testing and from customer feedback and incorporate the knowledge obtained into the next iteration cycles. The flexibility introduced through the agile processes allows for an efficient reduction of market uncertainty (will the product meet the customer’s needs?) and technical uncertainty (will the product be able to meet its functional and design specifications?) [7,8]. It has been reported that companies

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using Scrum have seen a notable increase of success in their product development through a limited time-to-market and resources employed for the development process [9].

In hardware industry, traditional deterministic-normative development processes are still widely used [10]. However, these processes are frequently regarded as “heavyweight”: too slow, too bureaucratic and too rigid [9,11,12,13]. In approaches adapting the concept of agility to physical product development the deliverable of an iteration loop has been interpreted as a prototype [10, 14]. This establishes the notion of a highly iterative prototyping process: an iterative learning and information gathering process leading to a rapid reduction of uncertainty.

In physical product development, the reduction of technical uncertainty is of particularly high significance due to the series ramp-up which follows the development phase [15]. Today, after the product development, numerous defects on the product side still occur resulting into an unstable series ramp-up phase. The elimination of defects during the ramp-up phase is time-consuming and costly as it has large technical implications on the product and processes [16]. Consequentially, a systematic decrease of technical uncertainty to a sufficient amount at an early stage before production ramp-up is desirable. The highly iterative prototyping approach proves suitable in this context as the continuous testing for problems concerning the product (and process) steadily optimises the product.

The shift from deterministic-normative development processes to agile processes in the form of highly iterative prototyping supports a notion that has emerged in the academic community: change replaces ab-initio design as the predominant paradigm [16,17]. Product changes resulting from external sources (customer requirements) or internal sources (product defects) should no longer be seen as “necessary evil” that must be avoided. Instead changes should be regarded as opportunities to systematically improve the system design before the ramp-up phase is reached. By means of engineering change requests (ECR) a continuous learning process from an early point on can be initiated. Through a fast feedback of information (from external and internal sources) to the design department, series product maturity for a stable ramp-up can be rapidly achieved. Concerning internally triggered changes, an enhanced capability of reactively dealing with a faulty product on the shop floor is required. A close co-operation of development and production departments in an interdependent engineering environment is indispensable for this. Consequently, agile processes supported through efficient an ECM have the potential to lead to a reduced time-to-market and to a more stable and thus shortened ramp-up phase.

After having introduced the importance of an efficient ECM for agile product development in chapter 1, chapter 2 illustrates difficulties connected to the implementation of engineering changes. In the following chapter, the methodology pursued in the research study is pointed out before chapter 4 gives insights about the findings and suggests a framework for an adaptive ECM. Chapter 5 gives detailed examples of the design of the framework. Lastly, the findings of the paper are concluded in chapter 6.

2. Problematisation

Analogous to the findings of a previous paper stating that knowledge management has a significant positive effect on the ramp-up phase itself [18], the present paper claims that the access to implicit knowledge and experience from the shop floor staff is also an accelerator of the product optimisation during the highly iterative prototyping phase. In this context, not only a fast data transfer from engineering to manufacturing, but also a timely information feedback to the design department via ECRs from the shop floor staff is a key capability.

Problems within the interaction process of design and production departments have recently been investigated by Fraunhofer IAO. Here, it is illustrated that companies which are required to react flexibly to changes already today, assess the coordination effort between the development and production departments as high [19]. It seems that strategies and approaches in use do not provide a comprehensive, effective and sustainable solution for an efficient change management. This is in conflict with the interdependent engineering environment requested earlier limiting organisational learning and thus the efficiency of actors and the responsiveness of the organisation [20].

The presentation of the problem situation leads to the following research question: how must the engineering change management in an agile development project be designed to allow for an efficient interaction between development and production department for a rapid product optimisation?

3. Methodology

As a research approach the paper follows a qualitative research process as an interplay between theory and empiricism [21]. The examination of current literature through a broad study of papers has formed the basis of the paper. The knowledge acquired through the literature study has been compared with observations based on an in-depth case study in a manufacturing company.

The case study was launched in May 2016 and is ongoing. The case company is a start-up in the field of electromobility. It develops fully electric vehicles and employs an agile development process in the form of highly iterative prototyping to prepare for series ramp-up. The engineering change process currently employed is supposed to be improved for this.

Methods of the case study have included process observations as well as semi-structured interviews and workshops with stakeholders involved, namely members of both design and production teams. The research work follows an action research approach as it aims at solving the particular problem of inefficient engineering changes and develops a framework for improvement [22]. For this, an analysis of the current challenges in the co-operation of design and production within the company’s prototyping phase is conducted. The development of a suitable framework as intended in this paper is supposed to underlie an improvement of the company’s ability to carry out efficient engineering changes. The implementation of first elements of the framework within the company is taken as a basis for a proof of concept.
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