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ScienceDirect

Procedia CIRP 52 (2016) 68 – 73

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Changeable, Agile, Reconfigurable & Virtual Production

Towards agile engineering of mechatronic systems in machinery and plant construction

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Abstract

Agile procedures (e.g. Scrum) are commonly used in rapidly changing environments of software engineering. Experts appreciate improvements in interdisciplinary collaboration, lead times and development costs by applying agile techniques as artifacts, meetings, roles and visualisation methods. Up to now, the use of agile procedures is still limited to IT-projects, due to a lack of profound knowledge in transferring agile techniques into interdisciplinary projects. This contribution presents the research work on Agile Engineering, a counterpart of Lean Product Development, by the systematic integration of agile techniques into the development process of mechatronic production systems. Thereto, an introduction and state of the art is given concerning the industry sector of machinery and plant construction as well as agile methodologies. The main focus of the paper is represented by the classification and comparison of Agile Engineering as well as the main features of integrating agile techniques into the mechatronic engineering process. According to the advanced research insights of the last years, Agile Engineering is a new enabler of success for establishing an agile production, providing promising approaches for coping with change and uncertainty efficiently.

Peer-review under responsibility of the scientific committee of the Changeable, Agile, Reconfigurable & Virtual Production Conference 2016

Keywords: Agility; Mechatronics; Engineering Process; Lean Product Development; Scrum

1. Introduction

1.1. Interdisciplinary engineering in machinery and plant construction

The machinery and plant construction is one of the most innovative, populous and top-selling sectors in Germany, leading the export trade of valuable equipment and machinery all around the world [1]. Especially specialized systems are profoundly custom-tailored, combining mechanical, electrical and software components [2]. In context of mechatronic systems, the importance of information technology rises progressively in matters of operation scope, innovation and value creation [3]. While customer integration and reaction times are low concerning consumer goods (e.g. configure-to-ordered smartphones), mechatronic production systems are mostly engineered-to-order in lot size one, deeply respecting customer needs [4]. As requirements have to be specified in a close collaboration, the development process can be characterized by a product and process co-progression [2].

To initiate an efficient development process, engineers have to cope with preliminary requirements from the beginning [5], as planning information merely substantiates during the progress [6]. As expenditures for necessary rework increase exponentially, the engineering phase is primarily in count of the pegged costs [7]. Hence, the interdisciplinary interaction of engineers is crucial for the success of a project, in which collaboration in teams, the conditions and requirements of the ordered product as well as the process and structural organization play significant roles.

1.2. Challenges and factors of success for an efficient product development

Coming from the challenges in mechatronic engineering, the increasing interdisciplinary collaboration, the rising complexity of requirements as well as shorten product life cycles mainly determines the efficiency of a product development process [9]. Thus, the specific factors of success in machinery and plant construction cover [3,10–13]:

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doi:10.1016/j.procir.2016.07.077

- professionalising the settlement and taxonomy of projects,
- definition of flexible, adaptive and improved processes,
- continuous integration of sub-products,
- cross-functional, interdisciplinary, self-organised and accountable teams as well as
- communication and involvement of stakeholders

To cope with these factors, key activities should mainly engage the improvement of methodical competences as well as the acceptance of new approaches [9]. This paper presents the results of the research work on the so-called Agile Engineering in machinery and plant construction, transferring agile procedures (e.g. Scrum) of software engineering into machinery and plant construction. Thereto, the state of the art is pointed out and the comprehension of Agile Engineering is discussed. As a practical aspect, the integration of agile techniques into engineering processes is outlined, before the paper closes with a summary and outlook of future activities.

2. State of the Art

2.1. Current situation in machinery and plant construction

Investigating the experience of applied procedures, [14] addressed the producing industry through a survey on mechatronic engineering in machinery and plant construction in 2014. From 158 online and written returns, 95 data records (symbol n) could be evaluated completely. Several theses could be stated concerning interdisciplinary collaboration, being summarized as impact results (see Table 1).

According to the survey results, less than 15 % of the engineering departments are structured in project teams. However, more than 79 % of all companies operate at global spread development sides. Thereby, change requests and coordination efforts are high or rather high in more than 70 % and 79 % of all cases. Likewise, more than 83 % and 86 % of all respondents concluded that the engineering depth is high or rather high in mechanical and software engineering, compared to 67 % in electrical engineering.

Asking for the application and knowledge on procedures within this disciplines in producing companies (see Fig. 1), the questionnaire distinguished between both conventional approaches (e.g. VDI 2221) of mechanical engineering as well as agile procedures (e.g. Scrum) of software engineering, which arose from the Agile Manifesto 2001, cp. [15, 16]. Thereby, the interviewed persons should specify, whether a procedure is adapted to the conditions, is applied unmodified or is rather unknown within the nearby environment.

Table 1. Results on conditions according to [14]

Thesis	Response	n
Engineering departments are structured in project teams.	< 15 %	92
Engineering sites at more than one location.	> 79 %	91
Change requests are high or rather high.	> 70 %	92
Coordination efforts are high or rather high.	> 92 %	93
Mechanical engineering depth is high or rather high.	> 83 %	92
Software engineering depth is high or rather high.	> 86 %	86
Electrical engineering depth is high or rather high.	> 67 %	89

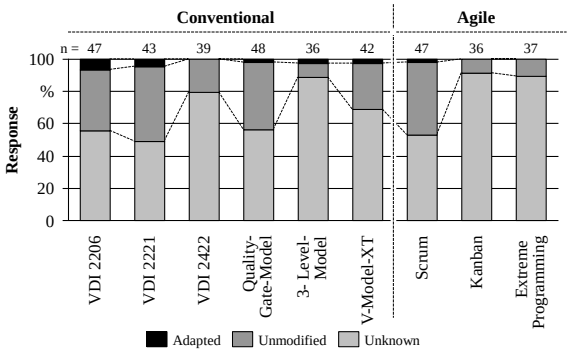

Fig. 1. Results on application and knowledge of procedures according to [14]

In regard of the participant's background, only the half is dealing with procedures themselves, particularly within the development department. Thereby, the VDI 2206 and 2221 as well as the Quality-Gate-Model belong to the most popular and unmodified conventional procedures. On the side of the agile procedures, only Scrum captures a comparable leading role, whereas Kanban and Extreme Programming are rather unknown. However, projects using agile procedures focus on IT according to [20]. Hence, this survey stated that engineering processes in machinery and plant construction are still construed to construction design, keeping to mainstream and established conventional approaches.

2.2. Agile Procedures

In 2001, software pioneers joined to declare "better ways of developing software" within the Agile Manifesto [15]. These experts came to four values of prioritisation (e.g. "individuals and interactions over processes and tools") as well as twelve principles of agility (e.g. "our highest priority is to satisfy the customer through early and continuous delivery of valuable software"), which play the most important role in efficient software development [15]. The implementation of these theoretical values and principles is realised by the application of agile procedures. In comparison to conventional procedures, which often focus on stage-gated phases and strict requirement specification [5], agile procedures expose the mind-set of agility, embracing change and uncertainty throughout the whole process [18]. Thereto, requirements are specified, features are realised and evaluated incrementally within an iterative period of time [19-21].

Until today, various agile procedures have been developed [19]. Among them, Scrum belongs to the widely used and most successful procedures, being applied in projects in and beside software development all-around [17, 22]. Thus, this paper concentrates on Scrum's agile techniques.

Particularly worth mentionable is the contrast, that Scrum defines no software-specific activities [19]. Instead, it follows the principles of Lean Management of Toyota Production System, which are common to engineering and manufacturing projects [19]. Coming from a novel interpretation, Scrum can be regarded as an elemental proceeding, being implemented by operative working steps within design states, aligned to common project milestones, cp. [8] (see Fig. 2).