Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 60 (2017) 145 – 150

www.elsevier.com/locate/procedia

27th CIRP Design 2017

Model Based Requirements Engineering for the Development of Modular Kits

Helmut Scherer, Albert Albers, Nikola Bursac*

IPEK – Institute of Product Engineering,at Karlsruhe Institute of Technology (KIT), Kaiserstr. 10, 76131 Karlsruhe, Germany

* Corresponding author. Tel.: +49-721-608-46472; fax: +49-721-608-46051. *E-mail address:* Nikola.Bursac@kit.edu

Abstract

The introduction of modular design increases complexity within product development and especially within Requirements Engineering. To handle this complexity, the approach of Model Based Systems Engineering is applied in this contribution. First, the origins of complexity in modular product development are introduced. Key challenges within Requirements Engineering are drawn up and then verified. A modeling method for requirements of modular kits is introduced and validated in the series development of hybrid drivetrain systems at a German automotive manufacturer. Increases in quality and a requirements reusability of over 80% were achieved. Thus, the capability of the modeling method is verified.

Peer-review under responsibility of the scientific committee of the 27th CIRP Design Conference

Keywords: Modular Design; MBSE; Systems Engineering; Requirements Engineering; Product Generation Engineering

1. Introduction

The development of modular systems is a productive and well-established measure in the automotive industry to increase the diversity of vehicles offered and to lower the variety of components in-house at the same time. However, the modular principle increases complexity within product development. In literature, multiple methods for the modularization of technical systems (transferring a conventional into a modular product generation) are introduced [i.a. 1, 2, 3, 4, 5, 6], some of them with a considerable focus on testability [7]. For the early stages, approaches have been developed [8, 9], too. However, for the series development of modular kits, there are only a few methods available. This paper focuses on Requirements Engineering, due to its large impact on a successful development. The paper describes, how the Model Based Systems Engineering (MBSE) approach can be used to support Requirements Engineering activities within modular kit development.

2. State of the Art

2.1. Modular Kit Development

In existing literature, SCHUH et al. – amongst others – claim modular kit development as a sequential process, which is independent of and prior to the actual product development [10, 11]. According to this, it is possible to develop all modules first and consecutively configure customer-ready products out of these modules. However, referring to the central hypothesis of product development of ALBERS, a product development is a continuous and highly iterative process, gradually increasing the maturity of the product [12]. Consequently, a lot of essential information about the products, which the modules shall later be part of, is not available at the time the modules are developed. This is why a modular kit development, which is independent of and prior to the product development, isn't feasible since the development of the modules cannot be finalized before the development of the products. Hence,

Peer-review under responsibility of the scientific committee of the 27th CIRP Design Conference
doi:10.1016/j.procir.2017.01.032

modular kit development must rather be considered a process permanently ongoing during product developments [13], leading to a large time scope (see fig. 1).

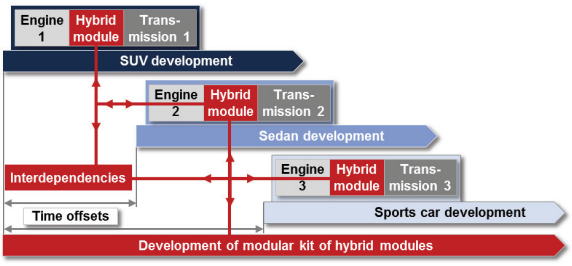

Fig. 1. Challenges of Modular Kit Development in the Automotive Industry

The development of modular kits being an ongoing activity, some specific challenges can be observed, especially as far as Requirements Engineering is concerned [14].

2.2. Requirements Engineering for Modular Kits

In this section, some general facts about Requirements Engineering and its relevance are compiled from existing literature. After that, key challenges within Requirements Engineering in the development of modular kits are drawn up.

Requirements Engineering is an essential element of a successful product development [15]. The quality of Requirements Engineering activities has a large influence on the quality of the result of a product development [16], those activities being: identification, documentation, validation and managing of the system of objectives [17]. Each of these activities brings its own challenges in industrial applications. The most significant factors within the automotive industry are: permanent enhancements and late modifications of the system of objectives as well as a large amount of stakeholders [18]. Furthermore, there is a huge demand for the reusability of the elements within a system of objectives, which must be achieved by appropriate approaches [19].

Now, the initial origins of complexity within the development of modular products are introduced and their immediate impact on Requirements Engineering is drawn up. As explained above, considering modular kit development as a steadily ongoing activity can lead to large time scopes. This leads to two key challenges for the development of modules:

1) Large time offsets: To use a company's resources (e.g. development teams, test benches, tools for computer aided engineering) consistently, vehicles using the same module are usually not developed simultaneously, but with offset program milestones (see fig. 1), thus extending modular kit development even further (10 years or more are common in the automotive industry) [20]. This means, at the beginning of the module's development, when all requirements for the module must be identified, a lot of information, regarding the vehicles which are developed later, isn't available yet. The initial system of objectives cannot be entirely completed. Hence, these time offsets within modular kit development lead to an increased uncertainty regarding the corresponding requirements within the module's system of objectives, and thus leading to higher complexity [1]. As proposed by ALBERS et al. [21], uncertainty of objectives, requirements and constraints can be expressed with the help of

- the degree of maturity (describes the completeness regarding the understanding and realization of an element of the system of objectives) and
- the degree of rigidity (indicator for the trustworthiness or rather the changeability of an objective).

2) Increased interdependencies: When looking at the initial goal of modular design to reduce the in-house variety of components of a company, one could assume modular kits can lower development efforts as well. However, one module now must satisfy the objectives, requirements and constraints of several vehicles. Thus, Requirements Engineering for the module's development becomes more complex due to the larger extent, variety and interdependency of the module's system of objectives [14, 22]. Furthermore, these interdependencies (see fig. 1) require close collaboration between the vehicle's developments and the module's development, leading to significant processual complexity [23].

The complexity of modular kit development can hardly be abolished since the origins of complexity cannot be changed. This is why new methods must be found that address the large times scopes and highly increased interdependencies within the series development of modular kits.

2.3. Model Based Systems Engineering

Even though working with a large number of documents (document-based development) is still widely spread, this approach is not capable of dealing with the high complexity of modular kit development [20]. In contrast, Model Based Systems Engineering (MBSE) offers new opportunities. It is based on a system-theoretical approach [24], in which a technical system and all data occurring in its development is captured and handled in central, computer-based product models [25]. These models replace the unmanageable amount of documents. It is accessible for all development stakeholders; hence, knowledge is made available more reliably. Thereby, MBSE enables large improvements regarding the consistency, perceivability, but also the reusability of the data [26]. Especially the reusability is important since the most products are developed in generations, with a share of subsystems, which are carried over [27].

The capabilities and benefits of the MBSE approach could already be proven in complex environments (e.g. in the development of space and defense systems [28]), yet the need for MBSE is rapidly growing in the automotive industry [29]. To handle the complexity in Requirements Engineering of modular kit development, the MBSE approach is applied in this contribution.

3. Methodology

To manage systems of objectives in conventional developments, some MBSE solutions are already applied in automotive companies. However, the research demand, that is