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Procedia CIRP 44 (2016) 61 – 66

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6th CIRP Conference on Assembly Technologies and Systems (CATS)

Using product and manufacturing system platforms to generate producible product variants

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Abstract

Product platforms have proven efficient as a means to reduce lead-time and increase product quality simultaneously. When using platforms to generate a family of products, the number of variants that need to be managed in manufacturing increases. To succeed with this, the manufacturing system needs to be maintained in a similar level of flexibility as the product platform. However, there is seldom a joint decision behind each and every conceptual product variant during development, regarding capability in manufacturing. For example, when considering producibility, some product variants require better tolerances than what the manufacturing processes can deliver. This uncertainty can be reduced, by making producibility analyses of a set of conceptual product variants. By performing several different analyses, knowledge can be gained, and joint decisions can be made about cross product-manufacturing aspects. The activities can be systematically arranged to gradually eliminate unfeasible conceptual product variants. In this paper we show how an integrated PLM architecture can be used to create sufficient knowledge as a basis for joint product and manufacturing decisions. The utmost company benefit of this is to reduce lead-time by taking manufacturing capability into account when developing product families.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)

Keywords: Product Platform; Manufacturing Platform; Producibility; PLM

1. Introduction

Platform-based design has traditionally focused on serving manufacturing with a low number of different parts. However, there is a shift in research towards, and an industrial need for, supporting reuse in the development phases. As a consequence, there is a risk that manufacturing aspects are not considered to the same degree, and the pursuit for a feasible producible variant will drive design rework activities, such as physical verification on a high number of variants, which is both time-consuming and costly. To maintain efficient manufacturing throughout this new paradigm, it is essential to better assess the producibility of the platform, and thus the family of variants that can be derived from it.

Modern computer aided engineering (CAE) tools are today capable of simulating various manufacturing capabilities, such as welding operations and robot paths. However, these simulations are typically used for process planning and as pre-production verification. At this late stages, changes to the product design are significantly more expensive than in the conceptual phases, due to the amount of engineering hours already put in into the detailed design, simulation, and possibly even physical prototyping, testing and verification.

Being able to better assess producibility in the conceptual phases would help propel the development towards a product adapted to desired manufacturing conditions, and minimize late changes. This type of concurrency has proven beneficial against late changes to products [1].

Set-based concurrent engineering (SBCE) advocates elimination of unfeasible designs based on intersecting design spaces from different domains [2], for example design and manufacturing. To ensure validity in design decisions, these need to be based on facts, rather than assumptions about the design and the manufacturing system.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)
doi:10.1016/j.procir.2016.02.132

This paper explores the possibility to use simulations related to producibility to narrow down the design space. To accomplish this, a number of design modeling and assessment tools are integrated into a Product Life Cycle Management (PLM) architecture. This architecture is used to virtually configure and assess a large number of possible concept variants simultaneously. The knowledge gained through this process is used to eliminate the concept variants with inferior producibility.

2. Research Approach and Scope

The context of this paper is producibility of platform variants in conceptual phases of development, and specifically the integration of CAx systems, displaying a PLM approach, as well as adequate and supporting platform processes. It is illustrated through a realistic case from the aerospace industry. The case is prepared in collaboration, and is based on a long running relationship, with industrial partners. The purpose is to get access to in-depth knowledge of products, manufacturing equipment and process knowledge. System specialists have been interviewed and relevant documentation, such as design guidelines and process descriptions, has been accessible and reviewed. During workshops, system specialists and researchers have revised and refined models in collaboration. A research question is formulated to drive the research: *how can a PLM architecture support assessment of producibility in platform concept development?*

3. State-of-the-art

This section presents a body of research related to platform development of products and manufacturing systems. It also gives an overview of producibility and IT support, commonly used in product and manufacturing development.

3.1. Platforms

Using a platform as a means of reusing knowledge has been receiving significant attention over the past decade [3]. The common view of a product platform is as a collection of different parts that can be combined into a variety of products [4], such as for example Lego.

The physical building blocks that constitute these platforms are created with a fixed set of customer requirements in mind. Therefore, they are sub-optimal for businesses where customers demand new functionality, resulting in large or frequent changes to the product, for example products with low manufacturing volumes. In short, they support a low number of variants in manufacturing, but provides little support for development [5].

To address this, there are other ways to keep the efficiency over time. For example, reuse could incorporate more than physical parts. In literature, the term platform is comprehensive, essentially incorporating any form of reuse of design and manufacturing knowledge [6].

Gedell [7] argue that a design engineer need more information than just the physical form of a design, for example why a subsystem looks the way it does and what function it realizes in order to reuse a design. Alblas, Wortmann [8] suggest reuse on a higher level using function platforms. Isaksson et al. [9] address the trade between commonality of modules from a manufacturing perspective with product performance. These platforms enable reuse of functions and the possibility to generate engineering variants.

3.2. Manufacturing System Platforms

Manufacturing platforms in various forms are discussed by [10] as well as [11]. The former uses modularization of the product and the manufacturing system as a way to increase the efficiency of development and manufacturing. The latter, Michaelis, describes how co-development of the product and manufacturing system platforms can be performed. Gedell et al. [12] speak of a unified product and manufacturing system platform. Michaelis et al. [13] also describe the use of functional models for representing manufacturing system platform, and how these can be linked to the product platform using operations as connecting elements. Koren et al. [14] suggests a reconfigurable manufacturing system, which accommodates the variety of a product family. The configuration serves to quickly adjust to changing customer requirements, while flexibility of the system itself serves the product family variation.

3.3. A Platform Model

To efficiently support manufacturing aspects into the product concept phase, platform models need to support modeling of both domains and the connections between them. Claesson [15] initiated the configurable component (CC) concept – a product platform model that was later extended to include the manufacturing system and manufacturing operations [16]. The model builds on reuse of functional features and supports the concept development phase through object oriented modeling and enhanced function-means (EF-M) modeling [17]. The CC concept features modeling of systems with alternative design solutions – the modular bandwidth, and parametric ranges – the scalable bandwidth, from which a number of different variants may be configured.

A platform described with the CC concept consists of several generic systems, each described with one CC object. CC objects can *use* other CC objects to compose themselves. A CC object can represent for example an entire aircraft, an engine or a part of the engine frame. Essentially, the CC

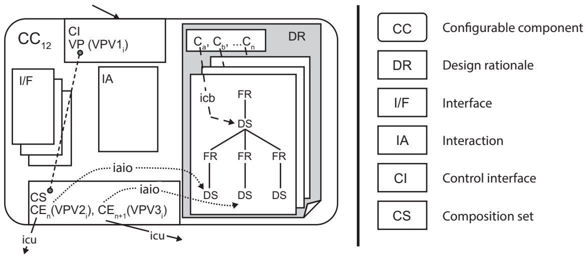

Fig. 1. The building blocks and relations of a configurable component (CC); composition element (CE), variant parameter (VP), variant parameter value (VPV), functional requirement (FR), design solution (DS), constraint (C), is composed using (icu), is an implementation of (iaio), is constrained by (icb) (adapted from [15])