Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 52 (2016) 134 – 138

www.elsevier.com/locate/procedia

Changeable, Agile, Reconfigurable & Virtual Production

Application of module drivers creating modular manufacturing equipment enabling changeability

Mads Bejlegaard[a]*, Thomas Ditlev Brunoe[a], Kjeld Nielsen[a]

[a]*Department of Mechanical and Manufacturing Engineering, Aalborg University, Fibigerstraede 16, 9220 Aalborg East, Denmark*

* Corresponding author. Tel.: +45-31227374. *E-mail address:* bejlegaard@m-tech.aau.dk

Abstract

The changeability of manufacturing systems can be of great importance for manufacturing companies to react rapidly and cost-effectively to market and product changes. Creating the basis for increasing the reuse and reusability of the manufacturing system then becomes critical since such capabilities would minimize the cost and/or investments that traditionally follows NPI projects and/or generally handling product variety. To accomplish the changeability of a manufacturing system one important enabler is modularity, which facilitates reusability. The basic concepts of modularity and platform architectures applied in product development can often be directly transferred to a production context though it does not necessarily imply that methods introduced as generic product modularization methods can be adopted directly with the purpose of developing modularized manufacturing systems. However, this paper adopts a method from product development literature to identify the optimal modular structure. Thus, this paper provides a methodology to apply module drivers in the design of modular manufacturing equipment, demonstrated on an industrial example.

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

Keywords: Module drivers; Modular manufacturing equipment; changeability

1. Introduction

The dynamics of today's global markets forces manufacturing companies to respond rapidly on the challenges that follows a demand for higher product variety and shortened product life cycles to compete [1]. Thus, capabilities to adapt to new system functionality and change capacity in order to introduce new products and ramping up production efficiently becomes important prerequisites to compete [2]. Creating the basis for increasing the reuse and reusability of the manufacturing system then becomes critical since such capabilities would minimize the cost and/or investments that traditionally follows NPI projects and/or generally handling product variety.

Traditionally manufacturing systems as the Flexible Manufactirng System (FMS) and the Dedicated Manufacturing System (DMS) is unsuitable to meet the requirements imposed by the global competitive market. Though the FMS enables high flexibility with its general-purpose machines, it combines low throughput with high equipment cost which makes the cost per part relatively high [2]. Likewise, the DMS has its boundaries since such systems needs to operate at high capacity to be cost effective [2]. A cost effective response to market changes is the Reconfigurable Manufacturing System (RMS), which combines the high throughput of DMS with the flexibility of FMS and is capable of rapidly adapt to new functionality and change the system capacity [2].

To accomplish the changeability of a reconfigurable manufacturing system one important enabler is process modularity, which facilitates reusability of a manufacturing system on different manufacturing system levels [3]. Applying modules has a long history in product development literature and methods can potentially be adopted for production system development purposes. Product family architectures integrating product modules and product platforms are applied for product variants planning purposes [4]. The aim is to achieve economy of scope by delaying product variety differentiation, capitalizing on commonality [5], and is

Peer-review under responsibility of the scientific committee of the Changeable, Agile, Reconfigurable & Virtual Production Conference 2016
doi:10.1016/j.procir.2016.07.059

motivated by an economic benefit that have been known for several decades [3]. These concepts of modularity and platform architectures has been adopted for manufacturing systems to cope with change and variety in current and future generations of products, and thereby to build adaptability into the manufacturing system.

It is generally accepted that products and manufacturing systems has to be co-developed so that the production system supports both the modular product structure and the production platforms, however the realization is not straightforward and uncomplicated. Such integrated platform development approaches [6, 7] exemplifies attempts to realize holistic platform strategies creating practical approaches to achieve product and production designs [8]. For instance, Michaelis [9] introduces the term Platform-based Co-development of Product and Production Systems similar to research on Co-evolution of Product, Process, and Production Systems [10, 11]. The latter also uses the term Process Platforms and can be seen as the evolution of cellular manufacturing, focusing on product family design and design of its production processes simultaneously [3, 12-14].

The basic concepts of modularity and platform architectures applied in product development can be directly transferred to a production context. However, that does not necessarily imply that methods introduced as generic product modularization methods can be adopted directly with the purpose of developing modularized manufacturing systems [15].

1.1. Research question and related work

To identify the optimal modular structure, different criteria for performing the modularization must be considered [16-18]. In regards to product development these criteria is referred to as modular drivers [17]. As mentioned in Brunoe et al. [19] considering such criteria is of paramount importance when modularizing a production system or establishing a production platform. Brunoe et al. provides a systematic exploration of production platform drivers adopted from product development literature. These module drivers are primarily defined based on the work of Ulrich and Eppinger [18] and Ericsson and Erixon [16], and it is demonstrated by examples that these drivers can be applied on varies manufacturing system levels. However, applying modular drivers for development of modular manufacturing equipment have not been carried out before to our knowledge.

It is well known that Design Structuring Matrixes (DMS) is a well proven tool to express system elements and develop their modular structure, and the ultimate goal of processing a component-based DSM is to cluster system components into modules [20, 21]. However, optimizing these clusters is either constrained by a predetermined number of clusters, number of components per cluster, or geometric properties [21]. Thus DSMs does not provide the information of how those clusters are arranged with respect to each other in the system architecture. To accommodate this, AlGeddawy and ElMaraghy [22] introduced Cladistics with the purpose of grouping components into clusters and to establish a hierarchical structure relating these components, and thereby to identify the optimal granularity level. Thus, Cladistics is also an attempt to optimize component clusters within a system architecture.

Applying modular drivers optimizing clusters of components within the system architecture is not a substitute to DSM and the Cladistics analysis but rather a supplementary decision tool.

Thus, the research question is as follows: *How can module drivers be applied to design modular manufacturing equipment?*

2. Methodology

This paper presents a methodology for modularizing the design of a variety of manufacturing equipment. The methodology is carried out on an industrial example with the purpose of making the fixtures more variant-oriented and to improve the design of a capital intensive process by standardizing modules. The method is carried out based on six different welding fixtures capable of handling 12 different sub-assemblies in a tack welding process. The immediate motivation to implement modularity across these fixtures is the influence of equipment variety on time and resource usage in terms of: 1) changeovers and retrieving of equipment, 2) storing capacity, 3) NPI, including design, manufacturing and installing equipment, and 4) Equipment investments. Therefore, the existing dedicated fixtures is converted into a modular system that can quickly change functionality (i.e. be reconfigured by changing modules) to accommodate a variety of product parts, instead of changing the entire fixture. The objective of the methodology is to derive and convert fixture functions into a number of strongly connected modules such that one or more of them can be changed when needed. By mapping functions across all fixtures change of modules to accommodate part changes are minimized because modules that remain unchanged and modules that might change is identified.

The presented methodology has three main activities as indicated below. The methodology applied is greatly inspired by the backbone literature and the related work introduced in section 1, and additionally research focused on development of modular and platform based production system architectures [23]. However, especially the Modular Function Deployment method by Ericsson and Erixon [16] has been a great source of inspiration deriving modules based on modular drivers and therefore partly adopted for this application in step three.

1. Domain analysis
2. Identify functions and means
3. Derive modules by use of module drivers

1) The scope of production platform development is based on a demarcation of a product domain. Deciding on the area of focus can be based on Group Technology trying to identify and capitalize on commonality across parts/products and manufacturing equipment. Reuse and reuseability is the foundation of handling variety and as parts/products evolve over time the boundaries of part/product families is affected as well, why co-development considerations of product variants and their manufacturing system is of crucial importance