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Technical Paper

Modular product platform configuration and co-planning of assembly lines using assembly and disassembly

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ABSTRACT

Formation of products platforms is carried out during the planning stage and very often separately from the planning of corresponding assembly lines. There is a dearth of literature which considers the different aspects of fully integrating platform design, product family formation, assembly line design, delayed product differentiation, and new concepts of mass customization. A Modular Product Platform Configuration model which uses assembly and disassembly for configuring product variants and Co-Planning of products platforms (MPCC) and their assembly Lines is presented. It is used to co-plan the common platform components and the associated product families simultaneously with the planning of its corresponding mixed-model assembly line. Using both assembly and disassembly to customize the product family platform in order to generate product variants is not commonly discussed in literature. It is defined as the formation of platforms for use to derive multiple products by including many components not shared by every product. The platform is then customized by assembling or disassembling components to form different product variants. The model is formulated using mixed integer mathematical programming to minimize the number of assembly stations and cycle time. Two case studies are used for verification and demonstration. They illustrated the ability of the MPCC model to integrate the planning of product platform, product families and the number of assembly stations required to assemble and disassemble components from mass-assembled product platforms to derive new product variants.

1. Introduction

An assembly line is a group of stations used to perform certain assembly tasks to produce final products (Fig. 1). Henry Ford is considered the father of the assembly line concept for mass production (Hounshell [1] and Alizon et al. [2]). The design, planning and balancing of assembly systems are not normally done concurrently with the formation of the products' platform configuration. Meyer and Lehnerd [3] defined the product platform as the commonly shared components among a group of products. If these common components are identified, then the planner can make use of the platform concept to produce product platforms first and customize them later. However, assigning these platforms and product families to corresponding assembly stations in one unified model is still lacking. Using both assembly and disassembly of components to customize platforms can increase platform effectiveness by producing more products using the same platform (Ben-Arieh et al. [4]; Hanafy and ElMaraghy [5]; Hanafy and ElMaraghy [6]). In most literature, products and platforms are designed and planned without consideration of their assembly lines, with the exception of very few papers. He and Kusiak [7], and AlGeddawy and ElMaraghy [8] proposed models that deal with both product families and assembly lines. Therefore, integrating the concepts of product clustering and families formation, platform formation and customization with assembly line planning into one unified model would represent a considerable contribution to current industrial practice. The proposed model facilitates effective and efficient co-planning of the assembly line and product platform.

This relatively new concept of using both assembly and disassembly to customize product platforms can be helpful when an increase in the number of shared components across different products is used in forming one shared platform. A good example of applying the assembly and disassembly concept is in the production of laboratory scales such as those produced by Sartorius AG Incorporation (Fig. 2)

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0278-6125/

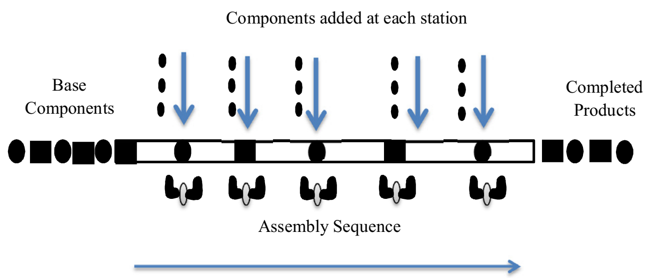

Fig. 1. Manual mixed-model assembly line representation.

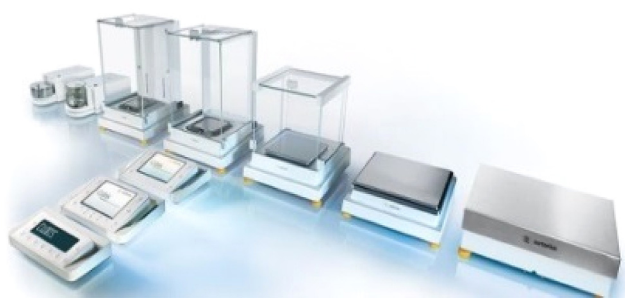

Fig. 2. A family of laboratory scales [http://microsite.sartorius.com/cubis].

which customize their products to fit different markets requirements and orders. The scale's main platform consists of 3 units: i) Weighing module, ii) display and control unit, and iii) A No Draft shield. This default platform enables the manufacturer to remove, for example, the No Draft shield after it has been assembled in the platform if it is not needed by the customer. Customers may ask for a high resolution weighing module which would be added when requested. Therefore, the main scale platform contains modules that are not shared by each possible combination of the laboratory scale. This illustrates the use and benefits of applying the concept of assembly and disassembly to derive different products from the same platforms. The novel model presented in this paper is the first that effectively combines the configuration of product families, platforms and assembly systems. It minimizes the cost of assembly by optimizing the platform configuration to allow using both assembly and disassembly of components to derive the desired product variant.

The proposed model is applicable to modular products of different types such as computers, electronic goods, weighing scales, home appliances, etc. The research gap in literature is discussed in Section 2, where there is a need to optimally co-plan an assembly line with product platforms and product families that using assembly/disassembly of components. These result would allow the companies to accelerate response to market, minimize lead time and decrease product and system development cost. This paper focusses on the co-design integration of products platforms, families and their assembly lines utilizing both assembly and disassembly of components to and from the product platform to customize it and produce product variants. Therefore, methods for separate design of products and assembly lines are not discussed.

2. Literature review

2.1. Product platforms

A Product platform is a set of sub-systems and interfaces that form a common structure from which a stream of derivative products can be efficiently produced and developed (Meyer and Lehnerd [3]. Lee and Tang [9] discussed the implication of components' kitting to postpone the differentiation of a large family of three-phase motors. Simpson, Maier and Mistree [10] described the concept of scalable product platform and the need to find the right balance between common parameters and scalable parameters. They proposed a Compromise Design Support Problem Formulation to design a product family of universal electric motors by scaling parameters to produce motors with very similar structures, but with variable performance. Martin and Ishii [11] developed various metrics to measure the ease and efforts needed to transform a certain platform to a different platform in the future. De Lit et al. [12] considered obtaining the product platform from a family of products using heuristics and graph theory considering only precedence constraints, and did not take into account the effect of demand on the product platform. Jose and Tollenaere [13] surveyed different methods used to identify platforms for product families and concluded that the objective of the product platform formation is to simultaneously increase the common components in platforms, and increase distinctiveness between the derived products. This necessitated finding new methods to increase product components' commonality in platforms while still supporting product variety. Tian-Li et al. [14] applied a genetic algorithm to partition a Design Structure Matrix (DSM) in order to produce common platforms for complex products and groups interactions. Al-Salim and Choobineh proposed two optimization models, using profit maximisation and option-value, to postpone the differentiation of a group of products by increasing the commonality between products. Ben-Arieh et al. [4] proposed a mathematical model and a genetic algorithm to increase commonality across different products by configuring single and multiple platforms through adding or removing components to the platform to form the final product. Their model considers product families and platforms only but not their assembly lines. Luh et al. [15] devised a cost model, including operation delay cost and penalty cost to compare the cost of producing copper strips with and without postponed differentiation. The model was only used to compare available redesigned production lines, not to obtain new ones. Rojas Arciniegas and Kim [16] used the