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Changeability focused planning method for multi model assembly systems in automotive industry

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Abstract

Series vehicle production is designed to produce effectively at a defined number of vehicles per period. Regarding market forecasts the overall market trend depicts an increasing demand for electrified vehicles within an uncertain propulsion concept vehicle mix. This demand cannot be predicted precisely because of volatile influencing factors such as governmental subsidies. Automotive companies are therefore confronted with the challenge of rapidly adapting their production systems accordingly. An approach to handle the variety of models within vehicle final assembly is to establish mixed model assembly lines. Since single model assembly lines are optimized for a specific production volume of one model, the subsequent integration of vehicles using alternative propulsion concepts into single model assembly lines stands as a great challenge in final assembly. Moreover, producing with optimal configured assembly systems after integrating an additional model is not ensured further on. To address this challenge, an approach for the greenfield planning of assembly lines using the concept of changeability is presented within this paper. The presented approach offers a new method to cover uncertainty regarding the future propulsion concept mix of assembly lines. This affects the initial setup of an assembly line concerning the line balancing and assembly equipment as possible subsequent changes to the assembly system increase costs. The target conflict is to minimize changes to the assembly system due to the integration of further propulsion concepts while ensuring cost efficient assembly. Hereto, the line balancing problem is solved for a fixed production volume ratio using a developed optimization algorithm. Thereafter, the production volume ratios are varied in order to identify an optimal solution for line balancing and assembly equipment. The uncertainty of volume ratios is considered in the integrated costs calculation module.

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Keywords: changeability; assembly system; planning method;

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1. Introduction

Customers of automotive companies demand an increasing amount of variants [1]. An approach of automotive companies to cover this need is to add an increased number of customizable options. This trend is further supported by the rise of electro mobility as the integration of an electric propulsion concepts can be interpreted as an additional variant to be produced.

Currently the demand for electric or hybrid vehicles is increasing [2; 3]. This demand is driven by external influencing factors such as governmental subsidies or commodity prices which are volatile. Therefore the predicted volumes to be produced vary accordingly [4]. In order to cover the resulting uncertainty a demand for highly flexible and changeable production systems occur.

The final assembly of automotive companies is confronted with several challenges concerning the assembly of different variants. The difference of the variants transfers to the difference in the bills of materials. Concerning electric mobility substantial distinctions regarding the bill of materials occur within the powertrain. Distinction in parts to be assembled leads to the conclusion, that also the assembly process is affected by different variants. Additionally the material has to

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be provided to the assembly line and moreover the order of assembly steps may be different due to other dependencies between assembly steps.

In automotive production there are two general approaches to design assembly lines – single model assembly lines (SMAL) and multi model assembly lines (MMAL) [5]. In order to handle the amount of different model variants an approach is to convert SMALs into MMALs or upgrade the amount of variants in MMALs. This approach respects the volatile but still low production volume of vehicles with electric propulsion concepts. It offers potentials for cost reduction since assembly lines operate efficiently and can be upgraded when necessary compared to setting up new assembly lines. On the other hand, the integration of new propulsion concepts causes different problems due to the optimized production flow of SMALs, limited space and assembly equipment.

Within this paper, an approach using the concept of changeability for the greenfield planning of final assembly lines within the automotive industry is presented. The concept of changeability has been applied to several topics in the field of production planning [6, 7, 8, 9, 10]. The presented approach focuses on two aspects: The line balancing under uncertainty regarding variants and model mix and the determination of the inherent flexibility of the line balancing solution.

2. Flexibility and changeability in production planning

As highlighted, final assembly lines undergo a new set of challenges due to the current overall market trend. On the one hand, the increasing number of powertrain variants that has to be respected and on the other hand, the changes in the model mix. These circumstances create pressure for the final assembly lines to keep up an effective production.

Therefore a target in final assembly planning is to plan robust assembly lines. Robust assembly systems are more resistant to changing external influences. Flexibility and changeability are two widely discussed concepts for implementing robustness [11; 12] (Fig. 1).

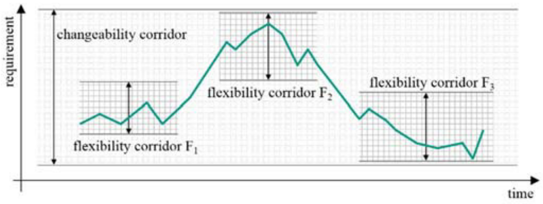

Fig. 1. Flexibility and changeability corridors [15]

2.1 Flexibility

Flexibility incorporates the possible solutions within an assembly line concept to react to small influences (e.g. fluctuations in demand or changes in model mix). Flexible solutions are characterized by quick implementation and low effort [13]. The range of flexible adjustments for such changes is defined as flexibility corridors and spans around the operating point of the system. Since adaptions in flexible systems come with low effort, the necessary resources need to be held available in advance [14]. The covered spectrum of a flexibility corridor is considered as an indicator for the robustness of the system. Therefore a larger flexibility corridor implies a more robust system.

2.2 Changeability

In case necessary modifications cannot be covered with available flexibility, changeability within the production system is a key factor for adaption. Changeability is a planned ahead solution space. It is defined as the ability to adapt to changing environmental influences by moving the flexibility corridors within the changeability corridor [15].

2.3 Costs of adaption

Regarding the planning of changeability a critical question occurs concerning the amount of changeability a system should inherently possess. A system neglecting changeability will save initial invest but in case of occurring change will result in high reconstruction and opportunity costs. In contrast a highly changeable system leads to a high initial investment but may yield operational inefficiencies, when the expected need for a change never occurs. Thus, identifying the optimal point in this trade-off is vital in strategic production planning. [16]

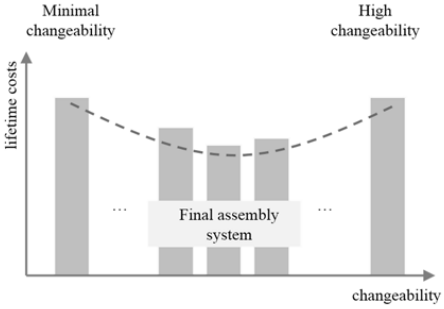

Fig. 2. Lifetime costs of changeable objects [16]

In the next chapter the method for greenfield planning that aims at investigating this trade-off through mathematical optimization is presented.

3. Methodology

The planning of final assembly consists of several tasks. The following planning methodology focusses on the uncertainty of variants and production ratios as well as on the resulting demand for a robust planning.

3.1 Deriving multi-objective optimization problem for the integration of an additional propulsion concept

The approach touches upon the field of line balancing, which is a mathematical method of allocating assembly tasks to work stations in such a way that under the consideration of precedence and other constraints a given objective function (e.g. investment costs) is minimized or maximized. Since each