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Maximising product possibilities while Minimising process change: A case of introducing Light Weight Material in Automotive Manufacturing

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Abstract

Companies are challenged to achieve maximised benefits in time, money and novelty when introducing new products or technologies into their existing manufacturing systems. This paper set the focus on the introduction of new materials into existing products and if the adverse effects on manufacturing will outweigh the benefits. An automotive case was studied where discrete event simulation was used as tool to evaluate process consequences when introducing new material and process technologies into the production system. The question concerned if discrete event simulation can verify production system capabilities even in early conceptual design stages. The case analysis is concluded by three challenge areas concerning early stages of production system design. The difficulties of evaluating operational key performance indicators early in design processes become evident and needed future research efforts within the area are pointed out.

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Keywords: automotive industry; light weight material; simulation; concurrent engineering; industrialisation

1. Introduction

The challenge of introducing new products or technologies into an existing manufacturing system has been the reality for practitioners for decades. Existing approaches include procedural processes such as production system design processes [1], [2], [3], set-based product development and industrialization [4]; organisational settings such as concurrent engineering and multi-functional teams [5]; and technical tools and methods such as simulation [6], rapid prototyping [7], design for manufacturing [8] and product families and platforms [9].

However, the academic approaches applicable in early design phases are in most cases based on a green-field design process. But as the most common situation encompasses both new investment as well as redesign; rearranging and reusing existing equipment and facilities, an elaborated design process is needed considering legacy systems, to ensure adaptability and sustainability [10]. Secondary, the approaches that do consider fit of new technologies into an existing manufacturing system are mainly applicable in later detailed design stages. This late involvement of manufacturing aspects in product development is witnessed also in industrial practice. In an early survey with data from 1991, only 9% of the investigated companies reported any type of early manufacturing involvement in new product development projects - that is, involvement in the concept development stage [11]. Hence, the challenge remains on how to maximise the combined benefits in time, money, and novelty (and thus maximizing product possibilities) while reusing equipment and minimising process change. And the greatest potential for impact is in early conceptual product development phases.

Still, it must be acknowledged that a design process is an iterative process where an analysis of the problem, a synthesis of solutions and an evaluation of solutions leads to a new analysis of the problem with knowledge given from the first evaluation and so on [12]. The design paradox of *'How to decide the whole, without knowing the parts? The parts depend in turn on the whole'*, indicates the iterative nature of design, especially as the design of a production system is naturally linked to the product design – two design tasks of two complex technical systems.

Concluding, the task of designing production systems and analysing process change while maximising the product

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possibilities by introducing new material and technologies into an existing production system, is a complex task with need of further research and engineering support. Design tools such as production systems modelling and simulation are anticipated to lead the way, but still the applications in early product design stages are few.

This paper set the focus on the introduction of new materials in existing products and if the investments in time and money within manufacturing will outweigh the product benefits, considering both short and long-term perspectives. The aim was to investigate the challenges and possibilities by using modeling and simulation in early investigations on introducing light weight material in automotive manufacturing. The simulations were expected to verify system capabilities and highlight challenges at this early product design stage. In order to fulfil our aim, following research question was formulated: *Can discrete event simulation verify production system capabilities even in early conceptual design stages?*

The empirical base for investigating the research question relies on a case within the automotive industry that considers the implementation of new lightweight materials into the car body. In the case, possibilities and effects were explored using a simulation of operational measures to estimate the impact on the production system.

Our results show the challenges by simple simulations of the needed changes caused by the new material regarding operational measures, and the lack of support for indicating the effects on the production system. The simulation of final key performance indicators need to be complemented by verification of key process criteria for development phase transitions.

This result can provide a basis for an extended discussion on the use of simulation of operational performance indicators in the early project phases, to predict the impact on the existing production system when introducing radical change on a product, such as a new lightweight material. It emphasizes the need of complementary procedures.

2. Material and method

To approach the research aim and to be able to answer the research question, a case had to be found that fulfills the criteria of a new material introduction into an exiting product to study the effects on the exiting production system. The choice of a case study approach can be argued with the need to study the mechanism involved in a real life situation [13]. As case, a car manufacturer was used that was implementing lightweight materials into their car bodies, requiring changes on the existing production system. In the studied case a part of the car body was exchanged with an aluminum part that couldn't be fixed anymore with the traditional welding technologies, due to the properties of the material. The new material thus required a new production process.

The findings presented in this paper is part of a larger research study including design work of the exchanged car body part and the proposal of the necessary changes within the body-in-white shop. The task was divided between two student teams, where one group focused the product design part and the other team the analysis of the production system changes. Within this article the particular insights of the product development team will be not discussed, nor will the design results. The researchers did not participate in the development teams, rather the researchers were passive observers of two development teams, studying how the use of simulation was done and if discrete event simulation could verify production system capabilities even in early conceptual design stages, according to the research question.

The team focusing on production system changes started by building a discrete event model (in ExtendSim) of the current state of the production line. In particular two stations were in focus for representing the current state as the supporting representatives of the company expected the biggest effects of the change there.

In a next step the key performance indicators (KPI's) were collected used by the company during operation and compare them with KPI's mentioned in literature. As a third step the design of a new proposal for the production line have been done under consideration the inputs received by the other team focusing the product design. Finally the new proposal was evaluated using the defined KPI's.

The case was set as an observation of an experiment of using discrete event simulation for this kind of task. The research analysis did not focus the solution as such, rather the encountered possibilities and challenges when using simulation of an envisioned production system in early product design stages. The researchers conducted the analysis of the experiences and experienced challenges were clustered into central themes, presented in section 4 Discussion. This research has been performed on a four-month project in interaction between industry and students.

3. Results and Analysis

The results are described in two perspectives: first observations on how the student team for production development used modeling and simulation as a tool for production validation in early design stages; secondly how the two student teams of product design and production development collaborated.

3.1. Observations on modeling and simulation of production

As mentioned, the current state of the production line was created as a discrete event simulation model using ExtendSim. Within the existing production line, two stations were identified as mostly affected by the intended material change and were, therefore, suitable to represent the current state. This finding was based on the inputs of the supporting company representatives and was further based on the first preliminary design proposals of the team focusing the product design. The identified stations were located after each other in the middle of the car body welding line whereby the first one was a Respot Welding and the second a Laser Welding station (first two stations in Figure 1). These two stations had different cycle times, and the car body was temporary stored in-between the two stations, modeled by a first in first out (FIFO) buffer in the simulation model. During the project, the