BPMN Process Design for Complex Product Development and Production

Dieter Roller, Erik Engesser

Institute of Computer-aided Product Development Systems
Universität Stuttgart
Universitätsstrasse 38
D-70569 Stuttgart, Germany
Dieter.Roller@informatik.uni-stuttgart.de
Erik.Engesser@informatik.uni-stuttgart.de

Abstract: In automotive development a lot of new power engine concepts were developed. Beneath the combustion engines hybrid drive systems and electric engines were developed. Consumers, public institutions and politics demand alternative drive systems to avoid air pollution, noise and the consumption of oil resources. Therefore electric drive products with innovative technologies were developed additionally. The problem for production plants is to today how these new technologies can be produced additionally to the existing cars with combustion engines. The objective of this paper is to design processes for complex product development with a lot of product variants an production processes which have to produce the complex product variants. The approach is to use BPMN 2.0 (Business Process Modelling Notation) to model the processes between development and production. BPMN 2.0 supports graphical process modelling and executable process modelling. The consequences of complex product development with high alternative drive systems to production lines were analyzed by BPMN models. A further approach is to use the research tool PROCAS (Process Optimization, Control, Analysis and Simulation) to analyze the consequences of high product variants in production. PROCAS use information of existing CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) systems. The concept of PROCAS is to determine how existing plants, production lines and inventories have to be extended.

1 Introduction

1.1 Problem and Challenge

The shortage of oil resources leads the development to find alternative drive systems. Rising oil prices causes direct cost of mobility [LI12]. The demand of alternative drives for vehicles is discussed by automotive producers, politicians and customers. Electric vehicles are one of the alternatives. Another motivation to produce electric vehicles is to reduce the atmospheric noise especially in big cities. The smoke in big cities like Beijing damages the health and wellness of the population. The air pollution caused by the traffic could be eliminated with electric vehicles. In future the utilization of electric vehicles will be in cities and for short distances. New types of cars are already produced by several automotive manufactures. For example in Figure 1 is a vehicle with electric drive based on hydrogen fuel cell shown. Like in [CO12] described hydrogen fuel cells produce electric power with high efficiency. Essential advantage of hydrogen fuel cells compared to batteries is that currently the chemical energy storage in liquid or gaseous form has a higher energy density. Difficulty of hydrogen operation is the storage in the vehicle.

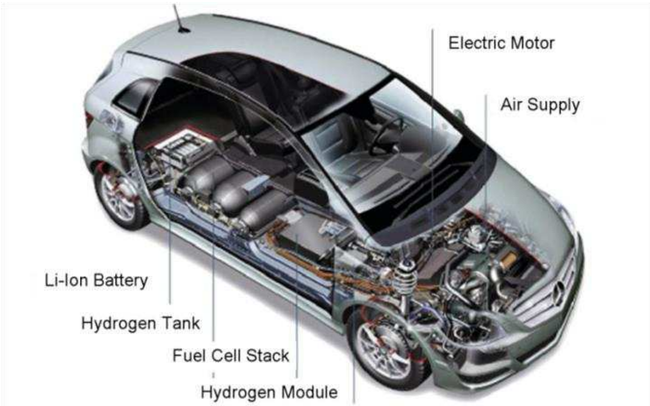

Figure 1: Vehicle with electric drive based on hydrogen fuel cell [CO12]

One research problem is how production of electric vehicles can be done. The existing production plants are manufacturing fuel powered vehicles. The demand of electric vehicles will not replace the fuel powered vehicles. So the variants of vehicle types will rising up. This means more complexity in production. Different kinds of product variants have to be built in the same production lines. In the automated production the robots have to do different kind of production workflows.

The research objective is to make an overview of the process workflow of product development, production and supply chain. The overview of the process workflows gives a possibility to illustrate how development and production planning and control departments work together. New process workflows for electric car production have to be integrated into the existing process workflows. Existing and new process models have to be simulated to examine if they work well and if there are any bottlenecks. After simulation the process workflows have to be optimized. One objective of the optimization is to reduce the complexity of the workflows. The objective of optimization is to avoid process wait times so that the production lead time can be reduced. A further optimization purpose is to reduce process steps so that the production can be done with less technical equipment like robots and with fewer employees to reduce costs. The development of PROCAS supports to model the development and production control processes in BPMN. Process workflows have to be designed graphically to describe and get a better understanding about the workflows. Additionally the BPMN process models visualize the interaction between the workflows of the development, suppliers, and production plants. A further purpose is the development of an interface to CAD systems to get information about the parts of fuel powered and electrical devices. CAM systems deliver data about production steps and operating procedures.

In chapter 2 complex product development is explained. Chapter 3 introduces BPMN 2.0 [LE12] modelling and process models of product development and production. Chapter 4 shows process modelling and simulation with PROCAS. The conclusion is chapter 5.

2. Complex Product Development

2.1 Extension of Product Structure and Production Steps

Product development develops product structures where all product variants are organized in tree structures. In figure 2 the extension of product structure for alternative hybrid and electric drive cars is shown. The complexity of products increase with new variants. It is enlarged with new variants, modules, part groups and parts. Additionally there are more parallel production steps. In figure 2 production step 0 is the final product variant. Step 1 is setting modules together for the final product. Complex product variants have a lot of production steps with various part groups and parts. Manufacturing processes like forming, painting, assembling and quality checking become more complex. Robots have to do more different kinds of production steps and production tools. More part and part group variants have to be delivered and have to be available for assembling. Operators have to be trained for various assembling and testing techniques.

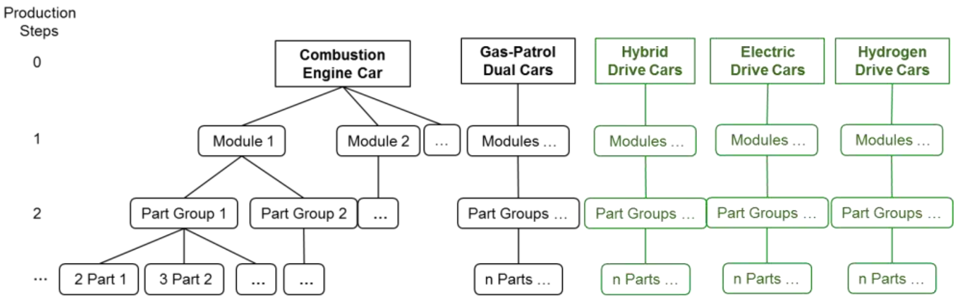

Figure 2: Extension of Product Structure and Production Steps

Thermal drives concepts remain the biggest market have to be produced with efficient technologies. Basic modules of a combustion engines are for example Combustion engine, fuel injection system, valve control system, water pump and charging system. A CNG (Compressed Natural Gas) car needs additional system modules for a dual system with patrol and gas.

As in [CO12] described, all concepts of electro motors are based on electric generated electromagnetic fields. The electromagnetic fields generate magnetic power by induction. The magnetic field remains in equal position for direct current motors. Threephase motors have a rotating magnetic field. Depending on the power, torque and efficiency factors different kind of electric motors are used for automotive drives. As in [RE11] described the operation of an electric hybrid vehicle is determined by the operation strategy. It depends on the optimization intention. Intentions can for example be emission or petrol reduction. The operation strategy controls the distribution of the required torque onto the combustion and the electric motor. Intention is to run the combustion motor in a favorable operation point. The classification can also be done by the absolute electric drive power P_{EM}. Therefore hybrid categories like micro hybrid ($P_{EM} < 6$kW), mild hybrid $P_{EM} < 6$-20 kW) and full hybrid $P_{EM} > 40$kW) exist.

3. Executable Process Modelling with BPMN 2.0

BPMN 2.0 Level 4 modelling is an XML language describing an executable process. Its focus is the XML details underneath [BR09]. In figure 3 a principle production process model is shown. The process model starts with receiving an order and order data as data object. First sub process is building the car body. If complex products are developed production processes have to be split into specific technologies. The exclusive gateway splits production processes with drive system variant information into the specific sub process. Therefore object data of drive system variant is needed. After installing the specific drive the sub processes are joined to the following sub process “assembly car”. The end state of the model is “car finished” output data as data object.

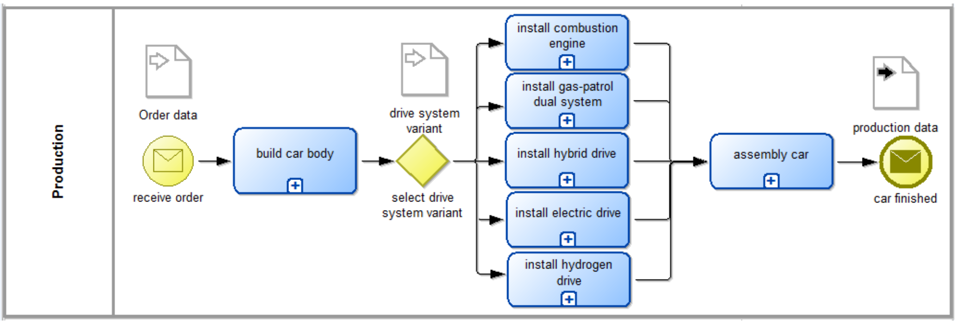

Figure 3: Example process diagram with data objects

A BPMN process model for product development is shown in figure 4. A process request message with the product specification is send. The first human task starts and makes the variant construction of components by CAD. The data object product specification is an input which describes for example product forms, sizes, functionalities, propositions. The designed component construction is the input for the human task construction of component assemblies and modules. This human task joins the components to assemblies and modules. The next human task integrates the modules into the product construction. A service task follows which analyses and simulates the product construction. If the result delivers any errors the previous tasks were informed and corrected. Finally the data objects product construction and analysis results are sent back as response message. The second pool of figure 4 shows the BPMN process model of a production control. The component, assembly, module and product construction are sent to the production control workflow. First human task is the production planning. Production processes and production facilities like robots and assembly lines are planned. Therefore CAM systems are used. Order requests are received by the distributors. The human task order sequencing creates the production order sequence. Next service task calculate component demands and sends a message request to the suppliers. After receiving the components the next task produce the product. Next task checks the product quality. If there are any quality defects rework have to be done. Finally the produced product is returned to the distributor.

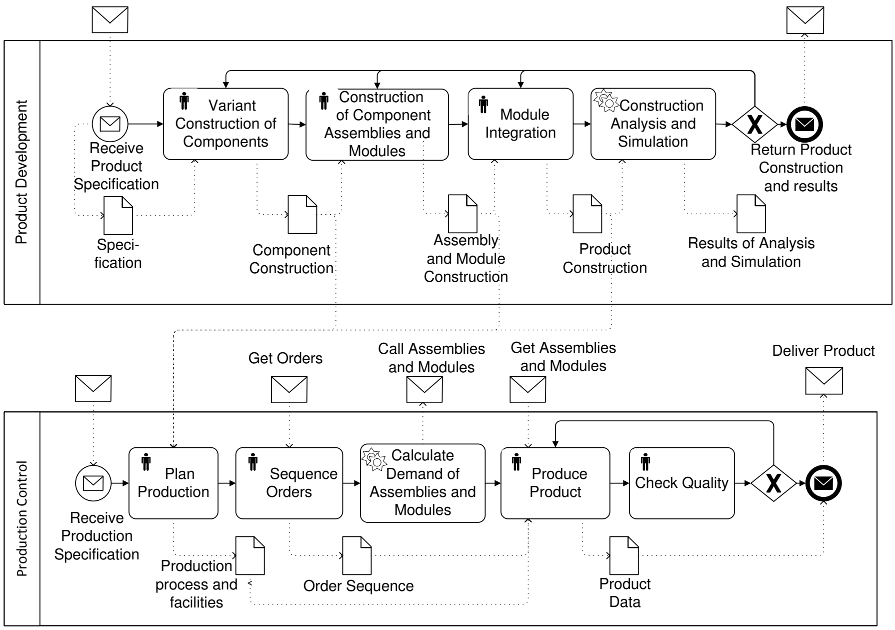

Figure 4: Process Modell of Product Development and Production Control

4 Process Modelling and Simulation with PROCAS

Figure 5 shows the concept of process modelling for the development and production of fuel powered and electric devices by PROCAS. The modelled BPMN process models are loaded into the database. In the shown left tree production steps of the product structure of figure 2 can be selected. A construction of an hybrid gear system is shown in the second window. Therefore CAD data is used as object data. The production workflow CAM data is also stored as object data. A robot assembly line is displayed in the right frame. The concept of PROCAS is to model and simulate BPMN process workflows [RE12]. PROCAS analyses the integration of new process models of electric drive production into existing production processes. Effects of variance increase of alternative drives and car bodies are analyzed. The complexity of production processes is evaluated. Consequences of construction changes on production processes are analyzed.

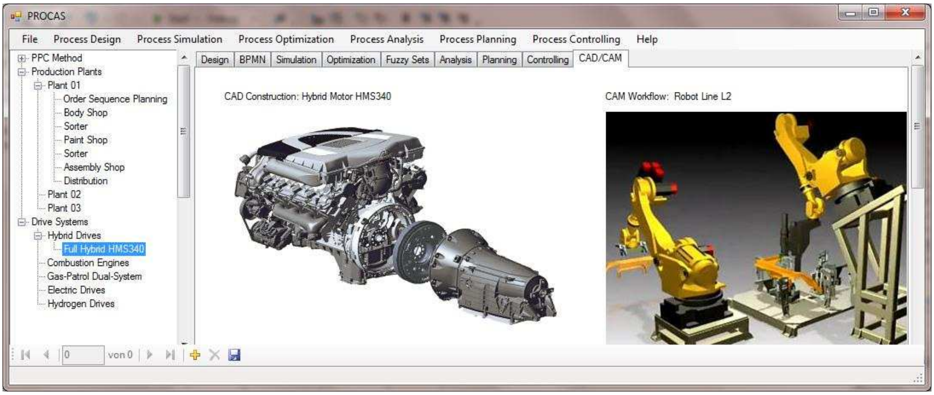

Figure 5: Process Modelling for Development and Production for Hybrid Drives with PROCAS

5. Conclusion

Products become more and more complex by new technologies and module variants. Product development develops complex product structures with various production steps. The rising complexity of product variants causes problems in production to produce all constructed variants. Executable BPMN 2.0 is an adequate approach to model processes of complex product development and production. The interfaces can be designed and executed. The concept of PROCAS is to integrate CAD and CAM information into the BPMN process model to simulate processes and interfaces. Further steps are to develop PROCAS to simulate existing plants. The simulation calculates how production lines and inventories have to be extended for more product variants in future. Input data therefore is BPMN process models of development and production, product structure, production steps, CAD and CAM data.

References

[LI12] Lienkamp, M.:Elektromobilität Hype oder Revolution?, Springer-Verlag, Berlin Heidelberg, 2012.

[CO12] Cornel, S.: Alternative Antriebe für Automobile, Hybridsysteme, Brennstoffzellen, alternative Energieträger, Springer-Verlag, Berlin Heidelberg, 2012.

[LE12] Frank Leymann, BPEL vs. BPMN 2.0: Should You Care, Second International Workshop, BPMN 2010, Potsdam, Germany, Springer-Verlag Berlin Heidelberg 2010.

[RE11] Reif, K.: Bosch Grundlagen Fahrzeug- und Motorentechnik Konventioneller Antrieb, Hybridantriebe, Bremsen, Elektronik, Vieweg+Teubner Verlag Springer Fachmedien, Wiesbaden GmbH 2011.

[BR09] Silver B.:, BPMN Method and Style (Code-Cassidy Press, 2009).

[RE12] Roller D., Engesser E: Modelling, Simulation and Fuzzy Decision Making of Distributed Production Control and Supply Chain Methodologies, IASTED, Crete, Greece, 2012, 781-044.