Towards an industrial testbed for holistic virtual production development

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Abstract. Virtual production development is adopted by many companies in the production industry and digital models and virtual tools are utilized for strategic, tactical and operational decisions in almost every stage of the value chain. This paper suggest a testbed concept that aims the production industry to adopt a virtual production development process with integrated tool chains that enables holistic optimizations, all the way from the overall supply chain performance down to individual equipment/devices. The testbed, which is fully virtual, provides a mean for development and testing of integrated digital models and virtual tools, including both technical and methodological aspects.

Keywords. Virtual production development, testbed, integrated tool chains, simulation, optimization.

1. Introduction

One of the critical aims of any value chain is to align and combine all objectives in various stages so that they work towards a common goal – increasing the efficiency and profitability of the overall production system. McAdam et al. [1] emphasis that the rewards of aligning the goals and objectives of an organization through various levels of decision making is substantial as misalignment of these goals may result in inefficient utilization of resources, loss of competitiveness, excessive cycle times as well as higher costs and loss of agility. Hence, it is in the best interest of all production managers to start thinking in terms of global optimization instead of achieving local optimizations, and aligning the strategic, tactical and operational objectives of the organization in order to obtain a system level optimization. In order to achieve global optimal solutions there is a need for integrating subsystems strategies and objectives. Integration of interacting systems can be divided into horizontal and vertical integration. The concept of vertical and horizontal integration has its origin in the domain of strategic supply chain management. Horizontal integration refers to the expansion of the business at the same level in the value chain whereas vertical integration on the

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other hand refers to integration on different levels by acquiring or expanding into the different value adding stages.

In this paper we investigate hos virtual production development can support global optimizations considering the vertical and horizontal integration. Virtual production development is well established in the production industry today and most companies use digital models and virtual tools to some extent [2,3]. Digital models and virtual tools are utilized almost in every stage of the value chain, all the way from product development utilizing CAE and process models of robot cells through simulation models of manufacturing lines and supply chains. However, although one of the most important aims of any value chain is to align and combine all objectives in various stages so that they work towards a common goal and thereby increase the efficiency and profitability of the overall system, the industry use their models and tools as isolated islands [4,5]. This is, however, no wonder considering the lacking possibilities to integrate the various models and tools with each other and perform holistic optimizations. For achieving an optimal production from an overall perspective, strategic, tactical and operational viewpoints, as well as the complex interactions between various operational levels in the value chain, must be considered in a holistic manner in the virtual production development process and the various tools used must be fully integrated with each other [6].

In this paper we suggest a testbed concept that aims to enable the production industry to adopt a virtual production development process with integrated tool chains that enables holistic optimizations, all the way from the overall supply chain performance down to individual equipment/devices. Through enabling the industry to use an integrated virtual tool chain and a fully virtual production development process that can be applied on current as well as next-generation production systems, the idea is to make it possible to achieve a truly optimal production and to assist managers in making high quality decisions by providing process/system understanding, insight and knowledge.

2. Industrial requirements on a testbed for virtual production development

To gather the most important industrial requirements on a testbed for virtual production development, we have undertaken open interviews with five industrial managers at AB Volvo and Volvo Cars, both large international manufacturing companies. From the interviews, it is clear that the overall purpose of the testbed from the industrial perspective should be to reduce costs and lead times, while at the same time increase adaptability and flexibility. Following are the specific industrial requirements stated by the interviewed managers, which also pinpoints the industrial relevance and needs for the planned testbed:

- The testbed should constitute a platform for increased collaboration and exchange between industrial companies, academic organizations, institutes, innovation actors and suppliers in implementing a holistic virtual production development process and realizing the virtual factory.

- The testbed should provide access to a fully functional integration architecture that allows fast testing and evaluation of different integrations, ultimately through a “plug-and-play” approach and preferably without cost.

- The testbed should provide an open technical framework that defines standardized, seamless integration of various digital models and virtual tools.
- This framework should be promoted both nationally and internationally and preferably become an adopted defacto standard in the longer run.

- The testbed should enable software vendors and system integrators, which are critical sub-contractors to the production industry, to adjust and extend their solutions so that they fit into an integrated tool chain.

- The testbed should include a methodology for working with holistic virtual production development, including how to deal with both vertical and horizontal integration of digital models and virtual tools and how to align the objectives of different stakeholders.

- The testbed should, related to virtual production development, give the possibility to take part of state-of-the-art, possibility to influence the technical development on an early stage and possibility to be at the edge of the future technologies.

The next section continues by describing the central concepts of the testbed.

3. Testbed concept

The testbed will be designed to be used for development and testing of integration between different digital models and virtual tools used at various operational levels and for various purpose. The aim is to practically enable an integrated tool chain and a holistic virtual production development process that fully realizes the concept of virtual factories and leads to production configurations that are optimal from an overall perspective, moving away from today sub-optimal solutions that are a result of the models/tools being used isolated. The testbed provides with a multi-level architecture, through which simulations and optimizations can be carried out in different levels using models with varied fidelity. This framework would support the multi-objective optimization and multi-level optimization. The architecture would allow each sub-system to be modeled as autonomously and considerable reduction of computing time can thereby be achieved by avoiding a high fidelity global optimization.

The testbed is fully virtual and will be accessible through standard web-based interfaces. The testbed is vendor and software neutral, and provides an integrating infrastructure with open and standardized interfaces that can be utilized by various actors for integrating existing as well as future models and tools. These interfaces will be based on information models and exchange protocols that specifies what data that needs to be shared and how it is exchanged. It should be noted that the testbed project does not involve only technical aspects related to the integration, but also methodological aspects related to how to work with horizontal and vertical integration and how to align organizational goals on different levels. Such methodology identifies persons / roles that interact, processes involved, which tools are used, what information is used, and how different purposes meet towards a common goal.

Testing in the testbed takes place virtually using standard, documented web-based interfaces. The testbed is vendor and software neutral, and provides an integrating infrastructure with open and standardized. The interfaces used in the testbed will be based on documented information models and exchange protocols that specifies what data that needs to be shared and how it is exchanged. There are two major types of tests that are meant to be performed in the testbed; (1) tests related to integrated tool chains for holistic virtual production development, and (2) tests of the integration itself. While the industry will mostly perform the first types of tests, the academy will perform tests of both types. The second type of tests are also expected to be undertaken by software vendors that will be invited to use the platform for modifying and extending their software with the purpose of making them work in an integrated tool chain.

For aiding companies in performing tests and evaluating a holistic virtual development process, it is important to develop a methodology as part of the testbed and provided as part of it. Except from including how to utilize the testbed and the integrated tool chain, the methodology should also include how to deal with both vertical and horizontal integration of digital models and virtual tools and how to align the objectives of different stakeholders. For enabling industrial actors to easily understand what an integrated tool chain means and what benefits a holistic virtual development process can provide, the testbed will provide the opportunity to test some of the most commonly used virtual tools.

An overview of the testbed concept and the integration possible to achieve by using the testbed is illustrated in Figure 1 below.

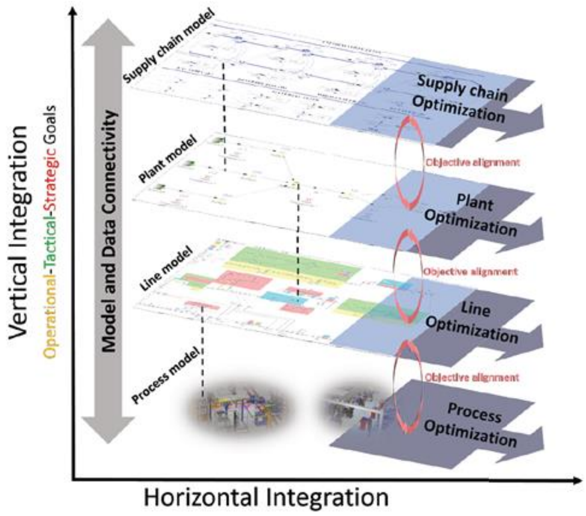

Figure 1: Testbed concept.

4. Methodological aspects

To succeed with a testbed for virtual production development, it is of high importance to consider not only the technical issues but also methodological aspects. This includes not only support in how to use the testbed, but also how to handle communication and cultural differences that are present between different departments in the organization, e.g. production and logistics, as well as the importance in involving the different stakeholders into the process of finding global solutions. Without shared information, common understanding of the holistic production system, good communication and understanding of each other's trade-offs, global solutions will not be achieved [7,8]. These aspects require a well-established communication and change management strategy [9]. There are different theories and philosophies that are aligned with the change management approach. Lean and Six-sigma are nowadays mostly referenced in the literature to pursue the continuous improvement changes in companies. But change is commonly perceived as a threat and clear communication in order to reduce the uncertainty is therefore a key issue [10]. Under an organizational change or improvement process, if the effort that is being made is not compatible with the organizational culture the process will hardly succeed [11]. Deeply established cultures in an organization represent an important barrier for organizational change [12]. Involving stakeholders in the early steps of conceptual modelling and simulation is crucial [8] and serves as the basis for the communication process and common understanding of the trade-off solutions [8]. This complete process adds layers of information that eventually gives a more holistic and unified view. Similarly, Bayer et al. [9] discuss the three sources of learning related with the simulation process: “the modelling process which leads to the model, which can then be simulated; all three are potential sources of insight” and discussion.

Considering that addressing conflicting objectives is part of the driving force behind the testbed, the simulation models and the optimization results can be viewed as “a vehicle for getting the right people together round a table and talking through the problem” and “get people to share a common vision” [13]. Robinson [14] and later on Robinson et al. [15] also present the facilitation power of simulation as an important role in supporting the discussion and an active involvement of the decision makers. Nevertheless, Taylor et al. [13] state that even in a traditional simulation project there are problems for the decision makers to extract all possible benefit from the process. Robinson [16] in its turn highlights the need for simulation engineers to have other capacities than just the right technical background, in order to be able to communicate and be helpful in a decision process. If this is important in a more traditional simulation process, it is imperative in holistic virtual production development given the exhaustive amount of data, multiple objectives and possible outcomes.

The challenge for the testbed is therefore to combine soft and hard operational research, which is still a novel approach [13,14]. The conducted research on the testbed will address how the communication and cultural change strategies of the companies related to multi-level, multi-objective processes are supported and coexist with their production philosophies by establishing a set of recommendations and guidelines.

5. Summary and next steps

Virtual production development is adopted by many companies in the production industry and digital models and virtual tools are utilized for strategic, tactical and operational decisions in almost every stage of the value chain. For companies which have not yet adopted the virtual production methods and tools, there is a vast potential of increasing efficiency and these companies need support to gain knowledge and courage to take steps towards virtual production. A problem with today’s virtual production development is, however, that the various models and tools are used separate from each other by decision makers that are dispersed over different units in the company. Each of the models/tools focuses on optimizing a specific aspect, e.g. supply chain, site, shop, cell or individual process points, which inevitably leads to sub-optimal solutions. In this paper we discusses the first steps towards a testbed for holistic virtual production development process. This testbed provides integrated digital models and virtual tools that enables to achieve a truly optimal production from a strategic, tactical and operational point of view with consideration to interactions between various operational levels. Using such holistic virtual production development process to optimize the production is the key factor for the production industry to leverage their effectiveness and to retain competitiveness.

The next step is now to design and implement the technical architecture of the testbed. This will be done according to, and using, the concepts of Industry 4.0, such as Internet-of-Things and Cyber-Physical Systems. Along with the technical development, the methodological development will also take place which is considered as a key factor for succeeding with establishing the testbed a defacto platform in the manufacturing industry.

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