Life Cycle Approaches on Product Realization: meeting the challenges of future production research

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Abstract
The global increase of manufacturing activities and the need for sustainability, calls for manufacturing strategies and technologies with reduced environmental impact. This paper presents a part of a strategic research initiative in Sweden, established by an ambitious industry-academic collaboration. A cross-organizational and cross-disciplinary focus area has been formulated to develop leading-edge production research for the future: Life cycle approaches on product realization. The research considers the total life cycle of the product and production system on three levels: (1) On a process level, with manufacturing technologies supporting products with high energy efficiency and low materials usage. (2) On a system level, with an extended production system design for the total life cycle of the production and product portfolio. (3) On an information level, with methods and tools covering the life cycles of products and production.

Keywords:
Life cycle, research program, product realization

1 INTRODUCTION
An increase in global manufacturing activities is evident. Globalisation and welfare improvements leads to an increase in product demand and increased manufacturing activity – we have seen a 43% increase of manufacturing activities worldwide 1996-2006 [1]. Meanwhile, the need for sustainability and absolute decrease in emissions and negative environmental effects, drive a need for technology and strategies that globally will reduce environmental impact of manufacturing. Thus, there is a need for large improvements in terms of resource productivity – “doing more with less”: [2] Future products will be based on an innovative use of emergent materials and with embedded intelligence for high strength, low weight and high
durability. Increasing customization and proliferation of product service solutions will also influence manufacturing activities of the future.

The objective of this paper is to describe the development, content and structure of a recent Swedish research initiative addressing these issues on life cycle approaches to product realization.

2 INITIATIVE DEVELOPMENT SETUP

In the Swedish governmental bill on research and innovation from 2008, manufacturing engineering was pointed out as one of 24 national strategic research areas. As a response to this, the initiative for Excellence in Production Research (XPRES) was developed.

2.1 Process and Participants

During 2008 the research groups within manufacturing from the Royal Institute of Technology KTH, Mälardalen University MDH, and Swerea – Swedish research institutes, joined forces with a number of world leading Swedish manufacturing industries, e.g. Scania, ABB, Volvo Construction Equipment, Sandvik, Atlas Copco, Bombardier, Saab, Alfa Laval, and also a number of SMEs working on the global market. The team developed a common vision based on the products that will be produced in 2015 – 2020, leading to three focus areas where this paper introduces one of these areas: Life Cycle Approaches on Product Realization.

2.2 Vision and Objective development

Swedish manufacturing focuses on processes with a high degree of added value, and products of complex materials and with high quality demands. Production is generally highly automated and based on manufacturing processes meeting stringent requirements on shape and tolerances.

When developing the vision, it was evident that manufacturing activities will have to reach a new level of sustainability, customer response and material/technological adoption. Reaching these needed advancements in science and technology, and the subsequent innovations they provide to manufacturing and economy, requires excellence and leadership in research. Meeting the challenges requires principles and technologies from several research areas. XPRES will establish an internationally competitive research and education environment to meet the challenges of world leading industrial enterprises; to provide sustainable and market responsive realization of future high valued products.

As summarized in Figure 1, meeting these trends will involve three enablers; 1) complex and integrated products with new materials, new technologies and new product configurations, leading to new production requirements, 2) a life cycle perspective on the product realization, and 3) adaptive and responsive production systems.

In the sustainability perspective, the vision is stated as a combination of Zero Net Waste and Total Information. Our vision is a Zero net waste system in terms of material/energy as well as the 7+1 wastes defined in the Toyota Production System [3]. The vision of Total information is to provide a direct access to coordinated information from different perspec-
tives, enabling a creative and coordinated use of digital tools, information and models throughout the life cycle activities.

3 FOCUS AREA CONTENT

The area in focus: Life Cycle Approaches on Product Realization, is in this paper described by three levels: process level, system level and information level. A common approach is to structure sustainability approaches in product, process and system levels, e.g. [4]. With our specific focus on production research, the product perspective is part of the process and system levels in terms of the interactions between product and production design.

The information perspective emphasizes the importance of information and communication technologies in future manufacturing, as mentioned in e.g. Manufuture 2020 [5]. The information level is described both in terms of selected examples of how total information enables new work methods on the process and system levels, and in terms of the required technologies on the information level.

Figure 1. Three identified key enablers based upon future drivers on manufacturing research.

The life cycle could account for the product life cycle or the production system life cycle. The life cycle is here divided in four phases: Design, Production, Use and End of life where the phases cover both the product and production system life cycle.
3.1 Process level
Waste and consumption of materials and energy in the manufacturing processes need to be drastically reduced. Specifically, processes should be developed for future products with high energy efficiency and low materials usage. In order to reduce materials and energy consumption, technologies should be developed for enabling “the 6R” over products’ life cycles [4] (reduce, reuse, recycle, recover, redesign and remanufacture). 6R should also be applied for manufacturing resources.

Based on the generic life cycle structure, the following specific production research aspects will be of interest on a process level:

- **Design phase**: Input is needed in a design phase to enable sustainable manufacturing. Specific techniques and guidelines on selection of material and production process, product life cycle management, ease of maintenance and remanufacturing are areas that need renewed attention from a manufacturing research perspective, in this case from a sustainability perspective.

- **Production phase**: Machining, assembly and logistic processes towards zero-emission. Researchers and practitioners have for decades worked on areas such as net shape manufacturing processes [6], dry or cryogenic machining [7], sustainable metal working fluids (MWF) [8], novel assembly processes and reverse logistic approaches. The specific focus here is processes for minimal energy and material usage.

- **Use phase**: Processes enabling sustainable aftermarket services will be explored for e.g. next generation of products based on light ultra high-strength steels and polymer composites, which today require a complete replacement when damaged.

- **End-of-life phase**: The needs of improved technologies and increased automation in pre- and post-fragmentation recycling processes are evident [9].

3.2 System level
Life cycle approaches on product realization is by and large a system issue. Productivity analysis schemes must be developed considering the entire manufacturing footprint and system design for the total life cycle of the production system as well as of the product portfolio. Based on the generic product life cycle, the following specific production research aspects is of interest on a system level:
Design phase: Life cycle analysis on a system level during the product design phase is a traditional stronghold within research and practice [10]. The specific production related research areas that could be applied in a product design phase are next generation of integrated design processes for production and product considering life cycle aspects, modularity schemes and reusability aspects of material and components.

One challenge is to enable the realisation of integrated processes through feedback of relevant information throughout the life cycle. Such relevant information would support integrated product- and process planning, flow simulation and layout design: 1) through supply of digital factory with models of new and existing equipment with information about wear and performance, 2) through communication of information and models between various stakeholders, 3) by enabling application of software services on company product models, 4) to match the product's requirements on the production, and vice versa; tracing the possible effects of changes, 5) enabling feature based operations planning based on product features, process models and equipment and tool models.

Production phase: The initiative will build on current efforts on integrating lean and green production during production design as well as operations [2],[11],[12]. Methodologies and decision support tools for process sustainability evaluation will be in focus, considering manufacturing footprint and supply chain aspects [13] as well process parameters and key performance indicators for sustainable manufacturing. It has strong links to environmental evaluation methods of manufacturing systems such as ISO 14044: Environmental Management - Life Cycle Assessment – Requirements and Guidelines [14].

The total information perspective includes the feed-back of measured product quality and performance; for control of the process quality and performance, and for re-planning and improvement activities. Further, software services for control and maintenance of production equipment.

Maintenance/usage phase: The product realization from design, throughout production and during maintenance must be interlinked when production system are designed. Local manufacturing could be a bridge between the production and maintenance phase of a product, creating a complete product service solution [15]. This is based on software services and feedback of information from maintenance to improve product and production system development.

End-of-life phase: The needs of economic and technical viable systems and concept for the next generation of product recovery are evident [9]. The information and logistic aspects are vital, supplying information required for reassembly etc as well as feedback from production and maintenance to product and production system redesign.

3.3 Information level – enabling technologies

Four generic categories of theories, methodologies and IT system principles are required, across all phases, to form the backbone for "total information" with coordinated information, knowledge and competence utilization in product realization:
• Principles and techniques for enabling coordinated information and interoperable systems: Manufacturing system terminology, concept modelling and ontology for systems integration and consolidation of information and knowledge about products, manufacturing methods, processes and resources [16],[17]. Further, principles for representing and managing information over product and production systems life cycles, requiring the representation of products, processes and resources and their interrelations from three perspectives: as required, as specified and as realized [16],[18],[19],[20].

• Human interaction principles, user interface and communication components to achieve an effective user oriented IT collaborative environment in production development, production, production networks and services.

• Authoring tools and applications to effectively and intelligently utilize developed knowledge and competence for process and operations planning, production investment, green production etc. which captures best practice, continuous improvement and innovative and new production methods, equipment and human ability [21],[22].

• Applications and techniques for simulation, analysis and optimization of virtual/digital manufacturing.

4 FOCUS AREA STRUCTURE: KEY ASPECTS

In order to fulfill the objectives, seven specific enabling aspects have been identified and will be developed together with the other two focus areas within the XPRES initiative.

4.1 Building a complementary consortium

In total, KTH, MDH, Swerea IVF and Swerea KIMAB in Stockholm have some 120 researchers in production development related areas. The research profiles of KTH and MDH are complementary. KTH has a strong profile in production technologies for current and new lightweight materials as well as digital engineering and modelling. MDH has a research emphasis on production system design, industrial automation and production maintenance. Swerea works close to industry with manufacturing processes and realistic material and process models.

4.2 Cross-organisation and Cross-disciplinarity

Increasingly complex engineering-based products and processes, and the shift towards product/service systems, call for a combination of interdisciplinary system-based research as well as focused deep knowledge in specific research fields. Developing in-depth knowledge through focused research, within a context of other research fields within manufacturing engineering, is a basis for scientific renewal and securing industrial relevance for the future.

4.3 Mechanism for scientific excellence

Manufacturing engineering research is inherently dependent on the close interaction between academia, research institutes and industry. State-of-the-art knowledge is created in a complex pattern of requirements, pre-
requisites, methodologies, empirics, implementation and deployment. A close industrial collaboration in combination with academic rigour is vital for reaching scientific excellence.

4.4 Ensuring industrial relevance
KTH, MDH and Swerea have common relations to many of the world leading Swedish manufacturing industries as mentioned previously. The XPRES joint initiative will together create even stronger links to the international companies within the region, and enhance their possibility to reach the international arena. The initiative enables an efficient industrial cooperation and will result in an increased number of bridge-building individuals among the partners.

4.5 Common infrastructure
An important cornerstone in a collaborative environment is communication, and the ability to visualize and test new ideas. Thus XPRES will establish an integrated physical and virtual lab with digital tools for real and virtual manufacturing and visualization of concepts.

4.6 Gender equality and diversity
The student recruitment must have access to all top talent, the research must be influenced by a multitude of perspectives and backgrounds, and the results and products must be developed in order to be applied and used by the entire population.

4.7 A structure for international collaboration
As the research questions as well as industrial development are increasingly global, there is an increased need for building research activities on international collaboration. Industrial and academic partnership programmes and projects will build a base for scientific and industrial breakthroughs.

5 REFERENCES


