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SIMULATION WITH SUSTAINABILITY ASPECTS IN THE MANUFACTURING SYSTEM CONCEPT PHASE

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ABSTRACT

The connections between product, processes and manufacturing systems are becoming more complex. Sustainability related issues are important and they are adding to the complexity of the design process. The amount of data that is needed for decision making is growing and multiple parameters and constraints must be considered simultaneously. Simulation and modeling can be used to analyze the performance of the product and production system, using traditional production performance measures and also taking into account environmental sustainability related performance measures. This poster presents research efforts for a novel concept for a simulation-based manufacturing and sustainability decision making system for the early product manufacturability evaluation and conceptual design phase of manufacturing systems. The research presented in this poster has been carried out within the frames of the EPES, "Eco-Process Engineering System for composition of services to optimize product life-cycle" international collaboration project co-funded by the European Commission.

1 SUSTAINABILITY ASPECTS IN MANUFACTURING DESIGN WITH SIMULATION

Sustainable manufacturing can achieved by using many strategies, such as improving process efficiency, reducing waste, and conserving energy and resources. Sustainable manufacturing involves interaction between multiple complex systems including those in manufacturing, environmental, financial, and social domains. Traditionally, engineering driven processes are affected by manufacturing knowledge and product performance orientated factors. However, nowadays this traditional concept of performance needs to be extended into a wider meaning, with sustainability being one of the main factors. The contribution is not only at the level of product, but applies as well to the manufacturing systems that are used for producing the product. Eco-constraints need to become a part of the wider assessment of the overall product feasibility analysis. This analysis needs to consider not only traditional cost and productivity oriented parameters, but also eco-constrains that are derived from the relevant stages in the whole product life cycle.

For an assessment of the sustainability of a product design, the overall product sustainability performance is the ultimate criteria and the process or manufacturing system assessment are only its sub-elements. To be specific, the sustainability assessment of a manufacturing process would not cover the other phases of the life-cycle of a manufactured product. An optimized manufacturing process does not necessarily mean that the product itself is optimal concerning its sustainability performance. On the other hand, to achieve an optimal overall sustainability performance when designing a product, the corresponding manufacturing processes and resources need to be optimized based on some sustainability criteria.

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Manufacturing system evaluation with Discrete Event Simulation (DES) has been proven to be suitable tool for the development of sustainable manufacturing systems, as shown by many authors in the past Winter Simulation Conferences. Integration of sustainability and environmental aspects to simulations is one of the on-going development efforts in many research institutes, e.g. Heilala et. al. (2008).

For manufacturing simulation with sustainability aspects, the first step is to ***define the scope*** of study and ***select suitable indicators*** for assessment. Manufacturing simulation is an event based process oriented study focused on material flows, resources, equipment and human operators. For addressing ***sustainability issues*** we are adding an energy flow study, (energy consumption), a more detailed study of consumables; e.g. materials, (dimensions, type), components, semi products, lubricants, chemicals, waste generation, and also an emission study (air emission, aerosol particle, water emission). The Life Cycle Inventory (LCI) data and Life Cycle Assessment (LCA) aspects could be incorporated into the simulation model, depending on scope of study. Sometimes it is sufficient to combine the results of a simulation with an LCA knowledge base as a post processing step. When incorporating ***LCI databases into simulation model***, the following aspects related to LCI databases should be acknowledged: 1) Data sources; 2) Data age; 3) Allocation principles; 4) Compatibility of generic database data with specific manufacturing processes, and 5) Data uncertainty. Those and other are input data quality issues should be considered.

Information models for supporting simulation for sustainable manufacturing are needed. Simulatio parameters and results could be stored using suitable Product-Process-Resource (P-P-R) metamodel. One example of an Engineering Knowledge Resources annotation metamodel is presented in Bemell-Garcia et al (2012). Sustainability data as shown here can be included in the metamodel. Other development efforst are ongoing e.g. NIST Sustainability Modeling and Optimization Project. (http://www.nist.gov/el/msid/lifecycle/sm_smo.cfm)

2 EPES SIMULATION SERVICE SYSTEM

European research project **EPES (http://www.epes-project.eu/)**, is developing a collaborative ICT tool, with web 2.0 features, for the assessment and optimization of technical systems from a product life-cycle point-of-view. In one of the industrial demonstrators the aim is to create a simulation tool for non-simulation experts' dedicated to the early product and manufacturing system design phase. The system provides new supporting services for the assessment of productivity and sustainability Key Performance Indicators (KPIs) on, for example, aircraft wing design (defined at the conceptual stage). By providing such services the EPES system enables the validation of production scenarios at the early stages of design and improved decision making for an optimal manufacturing facility will be supported. The end users of the EPES system will be "design for manufacturing" engineers, contributing in the assessment of design concepts. The EPES system will support them to make informed decisions on the performance of design concepts from the manufacturing perspective. EPES systems brings an opportunity to integrate the assessment of traditional manufacturing KPIs such as time and production rate with those related to the sustainability of the production processes. The essential questions answered through this assessment are:

- Productivity KPIs: What production rate can be achieved for a design using a given set of processes and resources?
- Sustainability KPIs: What are the energy consumption, the emissions and the hazardous material waste resulting from the manufacturing for a design using a given set of processes and resources?

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