Energy Data Acquisition and Utilization for Energy-Oriented Product Data Management

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Abstract

The development of energy-efficient products requires a consideration of energy information of all life cycle phases. Product data management (PDM) systems support this development process by providing the design engineer with relevant product data and models, but lack the incorporation of energy simulation models and energy usage measurements of manufacturing, operation, and recycling. This article defines requirements for an energy-oriented product life cycle management and investigates whether existing PDM systems can manage energy models and data. The utilization of prospective and retrospective energy data of machine tools is identified as being essential and is discussed in detail.

Keywords:

Energy Efficiency; Product Data Management; Energy Data

1 INTRODUCTION

Limited resources and increasing endeavors for climate protection emphasize the importance of the development of resource-efficient products. The development process has to consider all product life cycle phases, such as manufacturing, operation, and recycling [1]. IT systems in product development, e.g., product data management (PDM) systems, play an important role in providing design engineers with relevant models and data. In addition to models and data of product development, the approach of product life cycle management (PLM) tries to provide models and data of all life cycle phases, such as manufacturing, operation, and recycling [2]. A major task of PLM is to collect, store, and distribute knowledge of the products life cycle to all stakeholders [3].

Energy-oriented PLM considers the energy usage of products. It provides the design engineers with prospective and retrospective energy data of all life cycle phases. In product development, prospective data anticipates properties of a product in subsequent life cycle phases, such as manufacturing, operation, and recycling. Retrospective data represents the actual energy usage of an already existing product and its components, e.g., in operation. To provide prospective and retrospective energy data, an IT system for energy-oriented PLM has to integrate existing IT solutions of the product life cycle, such as PDM systems, manufacturing execution systems (MES), and enterprise resource planning (ERP) systems [4]. Furthermore, this IT system for energy-oriented PLM integrates product structure, process, resource, and cost models into life cycle product models with regard to available energy information. These life cycle models can be utilized to assess the energy usage of product designs.

PDM systems are fundamental components of an IT system for PLM [5]. PDM focuses on the management of product models that contain all relevant product data. Life cycle assessment (LCA) has been recently integrated into PDM systems to provide information about energy expenses of raw material fabrication and logistics. With the information about the kind and the amount of raw materials, LCA data can be utilized to estimate the energy usage of product materials. However, existing PDM systems insufficiently incorporate retrospective energy data from manufacturing and operation phases [6]. Additionally, prospective energy data is missing to estimate energetic impacts of product designs. Therefore, existing PDM systems cannot be utilized to assess the energy usage of a product in life cycle phases after product development [1]. The exchange of energy usage information of products is currently performed by implicit knowledge of domain experts and not explicitly by IT systems that support design decisions of engineers [6].

The contribution of this article is to define major functionalities of an energy-oriented PDM system that are necessary to support the management of prospective and retrospective energy data. State-of-the-art PDM systems are evaluated and it is investigated whether these systems already provide IT features that can help to implement these functionalities. As an example, use cases of prospective and retrospective data for machine tools are described in detail and a corresponding IT implementation is proposed.

The following sections are organized as follows: Section 2 proposes major functionalities of energy-oriented PDM systems from the design engineers' point of view and evaluates existing PDM systems with respect to these functionalities. Section 3 discusses the acquisition and utilization of prospective and retrospective energy data for machine tools. Section 4 presents an implementation of an IT system that collects and aggregates energy data of machine tools in operation. The section outlines an approach to integrate this data into the manufacturers' product model. Section 5 concludes the article.

2 REQUIREMENTS FOR ENERGY-ORIENTED PDM

This section specifies functionalities of energy-oriented PDM systems and describes enhancements of existing PDM systems that are necessary to incorporate prospective and retrospective energy data. Also, it is investigated whether state-of-the-art PDM systems already provide features that can help to implement the functionalities described.

J. Hesselbach and C. Herrmann (eds.), *Glocalized Solutions for Sustainability in Manufacturing: Proceedings of the 18th CIRP International Conference on Life Cycle Engineering, Technische Universität Braunschweig, Braunschweig, Germany, May 2nd - 4th, 2011*,
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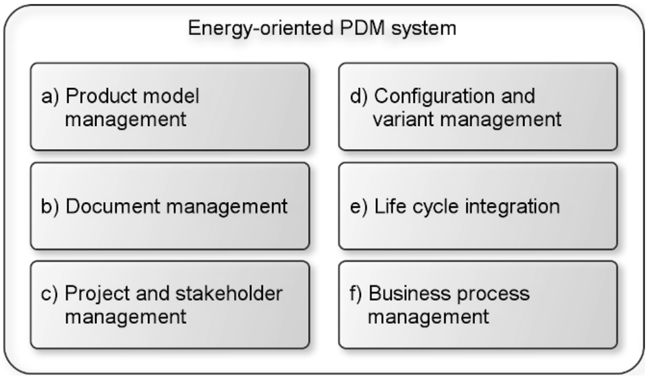

Figure 1: Major functionalities of an energy-oriented PDM system.

2.1 Functionalities of energy-oriented PDM systems

Usage scenarios of existing PDM systems mainly focus on the management of data created during product development. An extraction of decision-relevant knowledge or even decision-relevant data from other life cycle phases, such as manufacturing and operation, is scarcely supported. Therefore, an energy-oriented PDM system has to provide prediction models, which deliver prospective data that can help to assess the energy usage or the carbon footprint of products. The models focus on the prediction of selected properties of a product or a component in a specific life cycle phase. One example is the prediction of the energy consumption of a product in operation. Furthermore, an energy-oriented PDM system incorporates operating and maintenance data. This data is called retrospective data. With the help of this data, the design engineer can analyze the actual behavior of an existing product or component in specific usage scenarios. Also, this data can be used to compose new products based on components with available energy data. Thus, the management of prospective and retrospective data should be organized such that the design engineer can assess the energy usage of a product as early as possible in the development process. Since relevant life cycle data is stored in PDM systems as well as in MES and ERP systems, an integration of these IT systems is mandatory for an energy-oriented PDM system. One example is the integration of an ERP system at the customer site with a PDM system at the manufacturer site. With such an integration, maintenance data and utilization data of a machine tool used by the customer can be automatically transmitted to the PDM system of the manufacturer of this tool.

Since several domain experts are usually involved in the development process, collaboration management plays an important role for PDM systems. Additionally, this management has to involve suppliers and customers of the manufacturer [3].

Figure 1 depicts six major functionalities of an energy-oriented PDM system. An implementation of an energy-oriented PDM system should be based on IT features of existing PDM systems. The functionalities may overlap as some IT features can be utilized for multiple functionalities.

2.2 Evaluation and limitations of existing PDM systems

A first evaluation of IT features of existing PDM systems has been presented in [7]. This section expands this evaluation with the focus on the management of prospective and retrospective data. The following systems are evaluated:

- Aras Innovator® (Version 9.1)[1]
- PROCAD PRO.FILE® [8][2]
- Autodesk Inventor® and Autodesk Data Management Server (2010, Student Version)[3]
- PTC Windchill® (Windchill PDM-Link 9.1, PRO Engineer)[4]

In the following, the six major functionalities of energy-oriented PDM systems (see Figure 1) are discussed. Also, relevant IT features that can help to implement these functionalities and limitations of the systems evaluated are emphasized.

a) Product model management

A key task of PDM systems is the management of product models. Existing product models compose product components (assemblies, parts, etc.) in a hierarchical product structure that can be linked with other domain models, such as virtual models, (mathematical) simulation models, ECAD models, and resource (material) models [3].

In the PDM systems evaluated, domain models are usually treated as documents linked to the product structure. These models are not integrated into a life cycle product model and the information contained is used by specialized systems. For instance, simulation models are handled by the simulation system exclusively and the results of the simulation cannot be utilized by a PDM system (e.g., by component properties or features). Energy relevant data, such as energy usage measurements and environmental impacts of materials used, are also not integrated into the life cycle model or in part libraries.

In order to include retrospective and prospective energy data into an energy-oriented PDM solution, this data has to be linked to the product structure. Therefore, the product model management has to support energy considerations of product components. This forms a basis for the prediction of the energy consumption in different usage scenarios and life cycle phases for products to be developed.

b) Document management

The product structure is commonly used to link related documents to components of the product. Existing PDM systems focus on the integration of CAx documents and are also able to store any other kind of documents (e.g., text, drawings) [9]. The systems evaluated provide IT features to trace change histories of documents as well as features to import/export, classify, search, and archive documents. Apart from document-related features, the consistency between the product model and linked documents is essential in case of product model changes. Windchill, for instance, provides mandatory references that require the user to update documents referenced if the corresponding product structure element is changed.

All systems evaluated provide a repository to store the product model and all kinds of documents. Additionally, Windchill and PRO.FILE offer a customizable print and electronic archiving management as well as features to inspect document structures.

Energy and environmental data of the product can be stored as documents. Nevertheless, the systems evaluated cannot utilize the document content to extract relevant energy data. For example, a document that contains all consumers of a product and their energy usage in a specific usage scenario can be linked to the product structure. However, an identification of the main consumers based on the document content is not supported by the PDM systems evaluated.

1 http://www.aras.com/

2 http://www.procad.de/plm_eng/profile/pro_philosophy.html

3 http://students.autodesk.com/

4 http://www.ptc.com/products/windchill/pdmlink/