Niemann, J.; Ilie-Zudor, E.; Monostori, L.; Westkämper, E.: Agent-based product life cycle data support, in: Manufacturing, Modelling, Management and Control 2005, Edited by Chryssolouris, G. and Mourtzis, D., 2005, Elsevier, ISBN: 0 08 044562 4, pp. 105-110

AGENT-BASED PRODUCT LIFE CYCLE DATA SUPPORT

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Abstract: The paper presents a framework based on autonomous, co-operative agents for life cycle oriented data support. The framework identifies internal and external data sources for product optimisation. Depending on their types, the data are stored and permanently updated in different decentralised locations (web, company and machine). Initiated by the product manufacturer the databases will be permanently updated with changes or experiences from current operations. The data can be acquired from machine control, Auto-ID or other sources. Copyright © 2004 IFAC

Keywords: Life cycles, data logging, production systems, agents

1. INTRODUCTION

Industrial manufacturing companies concentrate their businesses more and more on engineering, assembly and services. They follow new paradigms to add value by customer orientation, systems management and services in the life of products (Anderl et al., 2000; Anderl et al., 1997; Niemann and Westkämper, 2004).

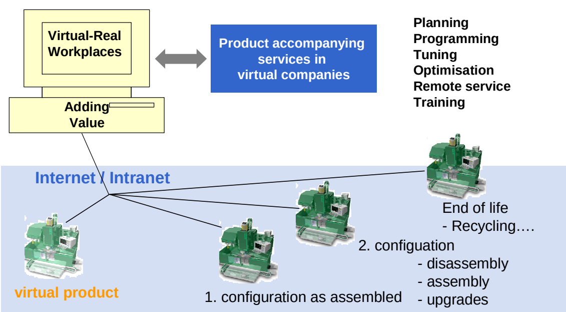

Fig. 1: The modern paradigm of life cycle management

Machine manufacturers and other branches like the automobile industry reduce their own capacities to the dominant or core technologies. Manufacturing of parts and components are done by suppliers or specialised companies. More and more the profit becomes a result of business operations in design, engineering, final assembly and service. These phases of production are the core competencies of companies, which produce strong market or customer oriented products and add value in the products life cycle.

Traditionally, product and process designers have been concerned primarily with product (process) life cycles up to and including the manufacturing step. Nowadays, the focus is shifted from the production to the products themselves covering all life cycle phases, e.g. material acquisition, production, distribution, use, and disposal. In other words, product stewardship is emphasised; the responsibility of companies goes beyond its operations to include the responsibility for their products' performance throughout the product life cycle (Figure 1).

In the processes of design and engineering, the functionality of products is defined. By assembly, maintenance and disassembly the real configuration, functionality and specific or characteristic properties for usage of products are finished (as build) or changed. In the usage phase special know-how on the design and characteristic properties, like specific process knowledge to optimise utilisation and performance, is required. The increasing technical complexity promotes product-near services and assistance of manufacturers. At the end of such developments, there are new business models for selling only the functionality of capital intensive products, rather than the products themselves.

Behind these tendencies there is a new paradigm: linking products in the Manufacturers Network from beginning to end for adding value and maximum utilisation. For this paradigm manufacturers need life cycle management systems, tools and technologies, which master the permanent product reconfiguration. Crucial for this is a holistic life-long product data support. The paper presents such a framework for a holistic life cycle information support system for manufacturing machines.

2. LIFE CYCLE PLATFORM

A future development has to take into account even the possibilities to implement all basic data of products into their internal information system. This would help to support all operations done with the product and surrounding activities with actual documentation (Feldmann, 2002; Gu, 1997; Kärkkäinen et al., 2003; Kimura, 2000).

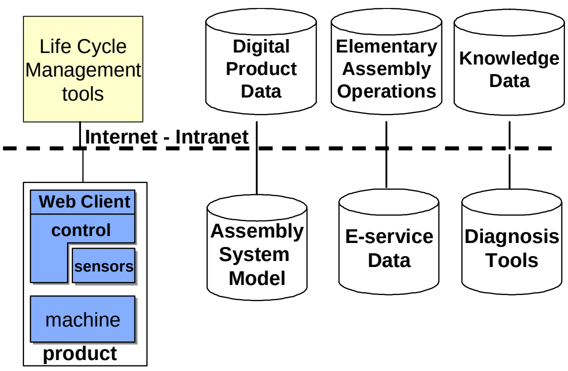

Fig. 2: Platform for the integrated management of products life cycle

Future management systems for the life cycle are open systems which operate on standards in communication and allow implementing product or customer specific IT applications. Figure 2 summarises such a platform with basic functions for communication and specific systems to support products and operations with data in all phases of their life. In order to perform this the product itself has to be monitored and different information about the actual product status have to be gathered, evaluated and disseminated on different levels. Therefore the implementation of a life-long product monitoring system is essential. The different activities are performed by different actors as there are product manufacturer, user, service companies or the recycler. All these different actors become partner in a network established for holistic product optimisation over the entire life cycle.

3. LIFE CYCLE INFORMATION SUPPORT

A general model must cover the entire machine life cycle beginning with the machine design and ending with the machine 'death' or recycling ('end-of-life'). Similar to a patient's file at a doctor's practice, this digital machine file can be considered as a document where all machine data and events have been logged. The different types of data can be divided into data for life cycle product tracing (discrete events, static) and life cycle tracking (continuous process behaviour, dynamic) (Figure 3).

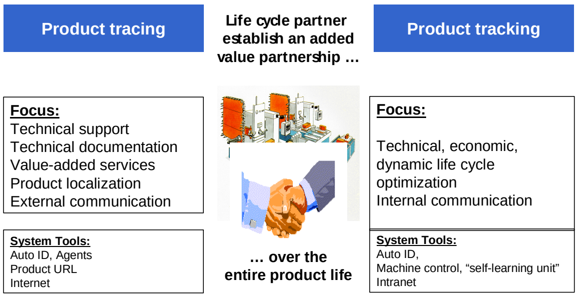

Fig. 3: Life cycle tracing and tracking

Product tracing mainly focuses on global parameters of the product concerning e.g. the physical location or activities performed over the life cycle. Mainly engineering and product data management (EDM/PDM) data are gathered to document conditions of 'discrete events'. Main objective is to create a record of activities along the product life cycle (Tichkiewitch and Brissaud, 2001).

The product tracking focuses on actual condition-orientated activities to mainly influence the current situation. The central objective is a technical and economic product optimisation in a dynamic environment.

The following sections describe these two dimensions more detailed. Merging these two dimensions means to get a detailed overview and controlling instrument (organisational, technical and economic view) to master product life cycles in turbulent and dynamic environments.

3.1 Life cycle product tracing

The activities in this dimension can be described as a life-long product tracing starting from design up to recycling.

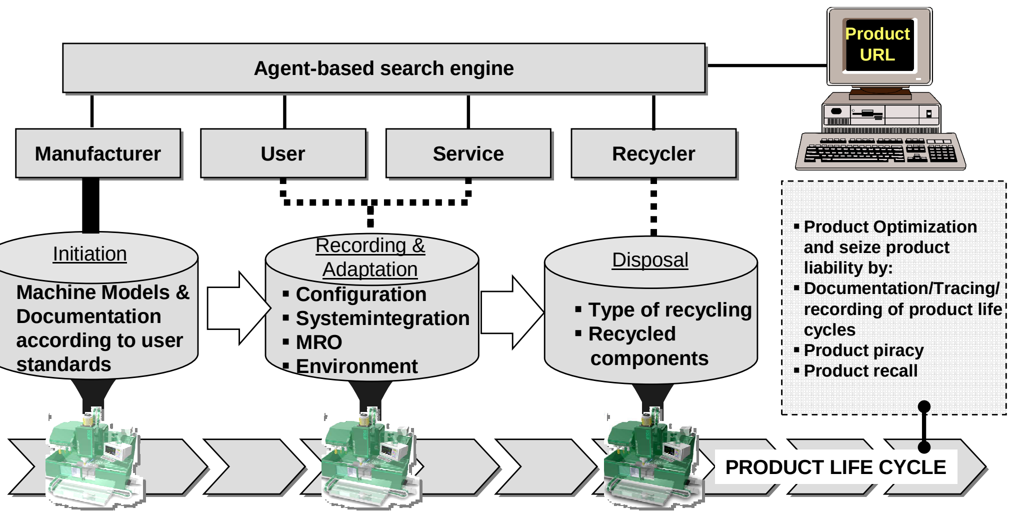

Fig. 4: Traceability of products over the life cycle

The main objective is to perform technical support and documentation for the product. The communication mainly aims at providing data concerning due dates, resources' identification codes and modification data for external life cycle partners. This allows recording a machine life cycle file, which provides information for subsequent (and previous) life cycle partners and helps to optimise future machine generations. Another aspect is to meet the requirements concerning laws of product liability and to prove/prevent product piracy. By electronic parts documentation falsified or irregular parts can be identified to avoid machine breakdowns or safety problems. In special cases the knowledge about the actual 'whereabouts of parts' can reduce cost in case of product recalls.

In order to prevent data overflow in one central data base all data gathered will be physically saved in decentralised systems. A software agent serves as a search engine, which provides information from other life cycle partners upon request. The agent operates with references to deliver a prompt reply to authenticated requests. The system will be operated via a web front-end with a product specific URL. The product specific URL avoids the current problems of different standards concerning data acquisition and supply (Figure 4).

The main objective is to create a network with external life cycle partners to access available additional product knowledge (Alting and Legarth, 1995; Niemann and Westkämper, 2004).

3.2. Life cycle product tracking

The vision of the digital factory of the future is to integrate all data of manufacturing resources into one (factory) planning environment. Due to a dynamic environment and operation processes the data are not static but have to be updated permanently. This applies also to manufacturing facilities and its configuration changes over the life span. The assigned data and documents have to follow the life cycle and have to be adapted accordingly on a permanent basis. Therefore the models and the knowledge about construction, design and configuration of the machine initially have to be set up by the manufacturer of the product (Westkämper et al., 2000; Gu, 1997; Kimura, 2000). The package also has to contain CAD product data, as well as the latest release of process models, parameter settings for optimal machine and tool operation. The models are integrated into/ attached to the machine according to the software standards of the customer and constitute an integral part of the delivery. After machine delivery to the customer the machine is integrated into the digital factory models at operator's side and all subsequent changes along the machine life cycle will be locally added to the given models (localised on the machine). From this stage on the data administration and updating is performed by the user.

The innovative approach here is to store all product-related data as well as models and knowledge about efficient machining operation decentralised directly on the machine. Therefore the machine knows about itself and how to fulfil its tasks best in close interaction with the machine control.

In terms of process control, it is however necessary to satisfy other requirements which make it possible to apply sensor-based and measurement techniques to the monitoring and guidance of processes. This also allows determining the current status of machines in an ongoing manner. Sensors record the relevant data from machines and processes. The process models feature the interactive links between input parameters and quality parameters relating to the components being manufactured and the current status settings of machines involved in the production process. This makes it possible to compensate for system-based deviations. An in-situ simulation can be used to determine status settings in advance for preventive purposes, and can also help to raise accuracy by adjusting parameter settings.

By this way the machine will be equipped with a 'self-learning unit' which is initially set-up by the manufacturer and is permanently fed with additional user knowledge and real experiences from current machining processes. This additional internally oriented knowledge chain leads directly to better process results and improved cost ratios over the product life cycle.

4. DATA MINING TECHNOLOGIES

In our approach we propose the implementation of product related information on two levels (in the products themselves and external databases), depending on the information type, using agent-based concepts and the Auto ID technique for external data retrieval.

4.1 Agent based data supply

Contemporary agent based techniques are widely used in quite a lot of application fields because of the advantages they can offer (Huhns and Stephens, 1999; Weis, 1999), provided by the characteristics of multiagent systems related to technological and application needs, natural view of intelligent systems, complexity management, speed-up and efficiency, robustness and reliability, scalability and flexibility, costs, development and privacy.

Some of the agent based architectures regard the elements of manufacturing systems, such as machines, operations, human operators, and even the manufactured product and its components themselves, as agents (Van Brussel et al., 1998; Monostori and Ilie-Zudor, 2000). Our concept complies with these approaches, but concentrates on the product agent.

To really cover the entire life cycle of a product is needed that the product agent (PA) that represents the physical product, does not end its life as in traditional approaches with accomplishing the manufacturing process, but further exists until the last phase of the product's life cycle, the disposal.

There is a large amount of information, which can facilitate the process of disposal. A part of this information is available at the production and might be incorporated in the product agent. An other part of the information relates to the use of the given product together with the modifications made on it during its life cycle, e.g. repair data (Ilie-Zudor and Monostori, 2001).

Taking the versatility of the products and the complexity of the disassembly/disposal process into account, the availability of as exact information as possible, is of key importance.

The product agent should include information on:

- the product life cycle,
- user requirements,
- design,
- process plans,
- bill of materials,
- quality assurance procedures,
- process and product knowledge
- maintenance and reliability
- the supply and demand of parts
- as well as information related to the product's end-of-life, such as:
    - the possible steps of disassembly,
    - the data that would help establishing the point of maximum financial profit (from this point onward the disassembly is not worth anymore; the data might change in time, and at the end of life of product, those should be actualised),
    - which parts can be sent to: recycle, reuse, incinerate or landfill,
    - type of waste that subparts from disassembly represent (solid, hazardous, liquid),
    - the data about the environmental impact of subparts as the disassembly proceeds.

A part of the necessary information can be common to a set of products centrally (e.g. the product type specific information), the other part can be intrinsic data of the given product (e.g. product specific knowledge related to the production and usage) (Ilie-Zudor, E. and Monostori, L., 2002).

Product take-back requires manufacturers to be responsible for collecting and dealing with products at end-of-life. The presented concept of product agent may facilitate this process.

4.2 Auto systems for product identification

For information collection during the PA's life cycle we suggest the introduction of Auto ID techniques. The introduction of Auto ID technologies is seen as a new way of controlling material flow. Auto-ID is the broad term given to a host of technologies that are used to help machines identify objects.

Auto ID encompasses various technologies such as: bar code technologies, Radio Frequency Identification (RFID) tags, smart cards, magnetic inks, biometrics, optical character reading, voice recognition, touch memory and many more (Auto-ID Center). Its main principle consists in the application of a tag containing information about and on products (parts and finished), which will be later read by a device called Reader (or interrogator).

The information contained on the tag, bar code etc. is not standardised at the moment, and different developers encompass different quantity of information, as this drastically influences the costs of the tag. Examples of information stored on a tag can be found in the approaches discussed in (Alting and Legarth, 1995) and in (Gu, 1997).

The location for maintaining product-related information should be treated decentralised, therefore we propose the separation of information on two levels according to the categories of product tracing or product tracking related data.

The concept proposed implies that components of the products have been applied Auto ID tags, which connects them to the local network and the Internet where the relevant data about them are stored. When the product reaches its end-of-life and will be brought back in the agent-based environment, the tag will make the automate connection with the database containing the data regarding its disassembly and disposal treatment, as well as with the software embedded in product agents for negotiating the tasks the product needs to be performed.

The PA drives its own disassembly process conform to the prescriptions for its end-of-life (e.g., the product will not be disassembled in all its components from the assembly process, but parts from the same material are kept together, as well as parts for which the disassembly is not worth it will be kept together for disposal).

Furthermore, tagged disassembled components are scanned and will be automatically synchronised with similar treatment components (e.g. parts that will be melted) and when reaching the minimum quantity necessary for processing start-up, will negotiate their own treatment process accomplishment. This may help considerably reducing storing costs of parts by their timely registration for processing.

A similar procedure is to be applied when/if the product needs maintenance or repair during its lifetime. When brought at the service centre, the tag will provide the data necessary for its identification, which will allow automatic connection to the database containing product service information. After service, the database will be updated with the new product-related data (what, where, when).

Beside the general advantages that Auto ID technology may bring to the entire supply chain to which products belong, there are particular advantages for PA management at products' end-of-life:

- eliminate human error from data collection when the product is returned to the manufacturer and needs liaison with it's end-of-life processing data,
- reduce inventories, as the components will spend the shortest time possible in stores, due to the automatically synchronisation with other parts of the same type
- improve safety and security, as the toxic or otherwise damaging materials will be kept in the inventories less time,
- eliminates inconsistencies or delays associated with lack of expert knowledge when a member of the team is unavailable at the arrival of the product, etc.

5. LIFE CYCLE SUPPORT NETWORKS

Today, the Internet offers a great variety of usable tools for life cycle management. The Internet uses tools, engines and robots (behind the interfaces) to search for information and knowledge. There are new standards for b2b (business to business) and b2c (business to consumer). Leading companies in the automotive and machine industries use the Internet as a platform for logistics and the administration of processes between OEM and suppliers. The technologies offer a broad spectrum of tools for managing the link between manufacturers and users wherever they are located. Examples of this include the management of the logistics of component supply for assembly and maintenance or technical support in the usage phase. The basic architecture of the Internet and of Intranets in companies' information technologies is illustrated in Figure 5. By this the machine is integrated into the local factory environment as well as linked to a world-wide net of supporting activities performed by other life cycle partners.

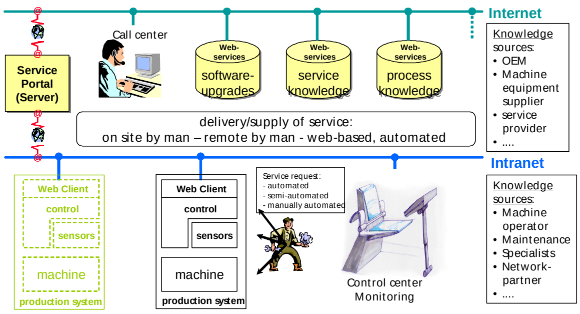

Fig. 5: Knowledge sources and sinks for life support networks

The figure shows a structure for the network of services based 'around the machine' to optimise the product life cycle. The network is characterised by connections which allow the transfer of knowledge and information automatically as well as manual. The nodes serve as a provider, server and distributor of knowledge. In this way, complex structures are generated which consist of knowledge sinks and sources whereby communication via the web is made possible using transparent interfaces.

Security techniques (firewall, en- or decryption) have to be adapted to the needs of manufacturers and be able to be operated in closed areas with service partners. Both the architecture of a product's control systems and Internet availability at each work place are important for assembly operation and maintenance. The diagnosis of machine functions and the monitoring of usage can be integrated into these systems and linked to the Internet. The same diagnosis systems are required for all changes in configuration.

6. SUMMARY AND OUTLOOK

The paper describes a general framework for the integration of different data sources and sinks along the product life cycle. The objective is to use these data for product optimisation in all different life stages. The relevant data will be stored in a decentralised way on the machine, the company's intranet and the internet. The data retrieval and supply can be realised by application of modern Auto-ID systems and agent-based search routines. Future machines will be equipped from the manufacturer with digital and holistic product documentation up to process models and simulation features to support product and parameter optimisation. By this the machine continuously gains knowledge about itself and is able to support and trigger manual or automated optimisation activities thanks to is 'self-learning unit'.

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