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Published in:
IFAC PROCEEDINGS VOLUMES

DOI:
10.3182/20050703-6-CZ-1902.01694

Published: 01/01/2005

Document Version
Peer-reviewed accepted author manuscript, also known as Final accepted manuscript or Post-print

Please cite the original version:
Remes, A., Suontaka, V., Saloheimo, K., & Jämsä-Jounela, S.-L. (2005). Development issues on the life cycle management of mineral grinding processes and equipment. *IFAC PROCEEDINGS VOLUMES*, *38*(1), 91-96. https://doi.org/10.3182/20050703-6-CZ-1902.01694

Author's accepted manuscript, published in 16th IFAC Triennial World Congress, 2005, Prague, Czech Republic

DEVELOPMENT ISSUES ON THE LIFE-CYCLE MANAGEMENT OF MINERAL GRINDING PROCESSES AND EQUIPMENT

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Abstract: The requirements set on the performance of industrial equipment during their life-time are increasing due to the growing demand to minimize expenses and maximize production as a result of tightening global competition. The demand to optimize the equipment performance is making the ability to utilize different services during the equipment more important. Equipment performance optimization includes integration of the process and maintenance information. In this paper the life-cycle management concepts are reviewed and a general framework and a case study in the mineral processing field is presented and discussed.

Keywords: Equipment life-cycle, Condition based maintenance, Standardization, Embedded automation, Mineral processing, Particle size analyzer

1. INTRODUCTION

At the present time, the level of embedded intelligence in process equipment is still relatively low compared to machinery in the manufacturing industry. It is important to increase the competence of process and production industries by implementing new information and communication technology tools for the process equipment. Management of the complexity of equipment networks during the life-cycle of the production assets will, in the future, require advanced embedded automation solutions. In other industry segments, the life time information modules are already applied and the economical results reported (Middendorf et al., 2002; Simon et al., 2000). During the life-cycle wide monitoring of the machines, feedback to product development will also be provided.

In recent years, new networked communication and control technologies have been developed and applied in production and processing plants. Considerable attention has also been paid to optimising the operation of the production machinery. However, technological advancements have not only changed the machines, but also the organization of the work. In many cases, therefore, the total optimality, availability and cost efficiency during the life cycle of the machines have not been taken into account. Improvements in efficiency can be achieved by applying embedded automation middleware to manage complex networked machines and distributed resources.

The aim of this paper is to illustrate and discuss different aspects of life-cycle management issues in the process industries. A unit process automation concept for a particle size analyzer system is presented as a conceptual case study in a mineral grinding process. The current state and the future directions of the field are also discussed.

2. KEY CONCEPTS RELATED TO LIFE-CYCLE MANAGEMENT

The following key concepts related to life-cycle management are presented: the life cycle of the process industry equipment, services for the extended product, and optimal asset condition management.

2.1 Life cycle of the process industry equipment

There are several ways to define the scale of the life cycle that is considered in process equipment management. From a manufacturer's point of view, this can be taken as the life cycle of a product line. This scale typically has stages ranging from design to manufacturing, marketing and use, the end of manufacturing and, finally, the end of the support.

On the other hand the analysis can be expanded to cover the whole solution-providing chain and the contribution of the individual equipment to a specific process. This user-oriented viewpoint starts the life cycle from the need of the new methods and solutions and ends to end of the use (which might be long after the end of support). The interconnections between product design, updates, services and optimization form an important management entity of the process equipment. Figure 1 illustrates the life-cycle steps from the user's viewpoint. The optimization framework and related middleware are discussed in section 3.

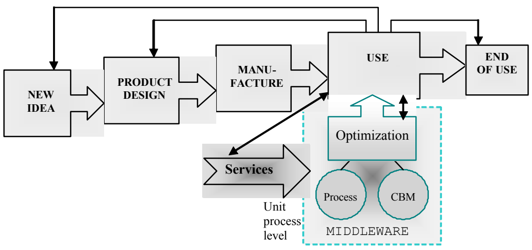

Fig 1. The scope of the process equipment life cycle from a user's viewpoint.

2.2 Services for the extended product

Thoben et al (2001) give a short definition of the extended product: extended product = physical product + support services over the product life cycle. The physical product can also be divided into a core product and a product shell. The core product can be considered as a part of the physical product, which performs the essential functions for which the product is designed. The product shell usually means the specific differentiations and detailed technical solutions of a manufacturer. Non-physical properties of a product are usually services and additional knowledge about the product or its functions (Hirsch et al, 2001). The concept of the extended product is illustrated in figure 2.

According to Hirsch et al. (2001), the support services over the product's life cycle contain expert services and product information. The life cycle should be considered from the end user's viewpoint (figure 1). Typically, the life cycle might even start before product development, when the equipment supplier is investigating the needs and expectations of new technology. At the other end, the time span might continue for decades after the end of manufacturing.

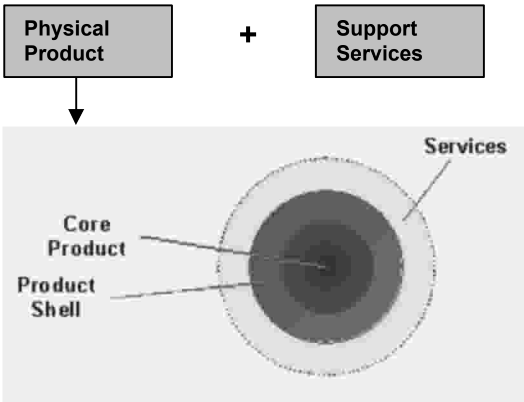

Fig. 2. The concept of the extended product.

The services are related, from the beginning to the end of the life cycle, to the following main fields: investment planning, product implementation, operation + updating, and withdrawal from operation. The idea is to provide services for the extended product during the whole life cycle. The information, computation and communication technologies available nowadays make it possible to do this efficiently. Figure 3 summarises the typical services for mineral processing equipment over the life cycle according to the preliminary extended product concept.

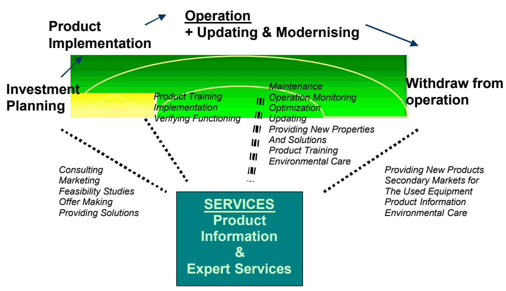

Fig 3. The services during the equipment life cycle.

The extended product concept has been widely utilized in consumer product markets. In the process equipment market, maintenance services have also become an essential part of the equipment delivery. Automation and information systems act as a link between the equipment and local or remote services. In the mineral processing industry, the extended product concept has, for example, been applied to a particle size analyzer. (Kongas, et al. 2003 and Remes, et al., 2004)

2.3 Optimal asset condition management

Equipment condition monitoring and future health estimation methods have not been widely implemented in mineral processes. A special effort should be made to combine the process measurement information and production plant maintenance information system to produce recommended action schemes. The problem field covers life-cycle scale information handling, asset maintenance optimization and operator support systems.

The framework for managing machine condition monitoring and health assessment is presented in figure 4. The concept is based on condition-based maintenance (CBM) (Bengtsson, 2003), with seven module layers.

The first *sensor* layer contains data acquisition from process and maintenance systems. The second phase includes different *signal processing* methods, depending on the applications. *Condition monitors* compares the signal from the previous layer and other condition monitors to the expected values in order to produce alerts. The *Health assessment* modules prescribe whether the health of the monitored component, sub-system or system has degraded. The *Prognostics* layer estimates the future health of the asset and calculates, for example, the remaining useful life. The *Decision support* module generates recommended actions and alternatives, based on the prognostics and health assessment information. Finally, the *presentation* layer presents the information from all previous layers to the operator in a structured form. The presentation module could be located in regular machine interface and in the upper level control system.

3. A FRAMEWORK FOR INTEGRATING THE PROCESS EQUIPMENT

Extensive utilization of information and communication technologies is needed in order to implement the process and maintenance optimization methods. Networking is also an efficient way to provide services.

3.1 Embedded unit process automation framework

The core concept in which the methods are to be applied is the middleware automation level (figure 5). The platform integrates the complex network of the production equipment with computing, communication, sensing and control resources. The functionalities embedded in the middleware cover the management of the whole process system at the life-cycle scale. The methods can utilize the connection to upper level systems and remote resources, and the information refining tools provided by the middleware platform.

The unit process automation middleware offers an interface to apply the optimization methods to the whole process entity. The optimization can be categorized for both process and maintenance optimization.

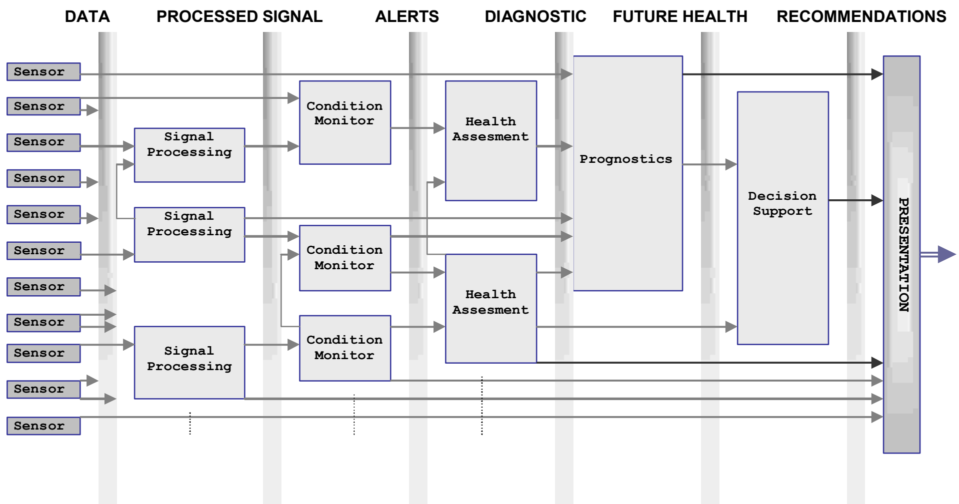

Fig. 4. The framework for condition based maintenance (CBM) of the process equipment.

The platform provides the life-cycle management with extensive use-time data logging and information processing capabilities. The concept of the extended product with life time services can also be applied more efficiently.

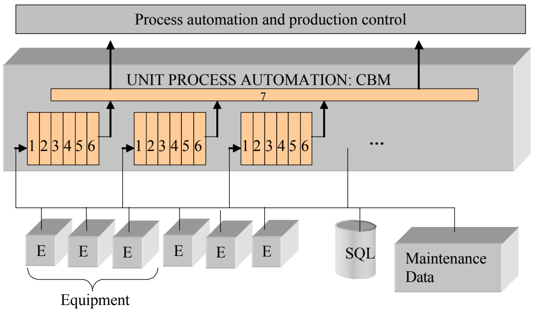

Fig 5. The unit process automation framework and an example of the middleware for condition-based maintenance (CBM).

3.2 Standards related to the framework

In order to ensure the compatibility of the automation system, the equipment and the circuit, the standardization issues should be taken into account. Several open standards and specifications for embedded systems have been proposed by various organizations. The main challenge is to predict which of them will gain general acceptance and become more common in the future. Here A brief overview of the current standardization related to unit process automation is given in the following.

The MIMOSA organization (Machinery Information Management Open Systems Alliance) draws up specifications for the integration of operations and machine information (Anon., Mimosa org.). One of these is a reference model for condition-based maintenance (OSA-CBM), presented in figure 4. The reference models do not specify the implementation of the methods. Some detailed implementation solutions are available, for example, for OSA-CBM in OSGi (Open Service Gateway initiative) (Anon., OSGi org.). The OSGi alliance has developed software components to provide remote services to distributed industrial equipment.

A FDT/DTM specification has been developed for field bus connected devices. The FDT (Field Device Tool) communicates with field devices containing DTM (Device Type Manager) (Anon., FDT org.). The FDT/DTM is independent of the communication protocol and software environment, and ensures the compatibility of different manufacturer devices. The DTM component of each device encapsulates all the device-specific functions and data. This enables easier configuration of the devices with one FDT application.

Up until now, the open communication specifications have been of at least two major types. The OPC (Ole for Process Control) is nowadays considered to be the common standard interface. In recent years the XML language (eXtensible Markup Language) has received increasing interest in data interchanging and representation, for example, in product data management (PDM) systems.

In addition to the open standards, the ISO organization has also launched standards related to product data management and condition monitoring (Anon, ISO org.). The ISO 13374-1 standard defines condition monitoring and diagnostics of machines, including data processing, communication and presentation. In product data management ISO has a standard 10303-11 EXPRESS, which defines the language for Standard for the Exchange of Product Data (STEP) definitions.

4. A PARTICLE SIZE ANALYZER – CASE STUDY OF LIFE-CYCLE MANAGEMENT IN MINERAL GRINDING PROCESSES

A unit process concept for a grinding circuit is considered as a case study of life-cycle management in mineral processing,. The goal of the study is to discuss the major development focuses and to define a framework for implementing new optimization and life-cycle management methods in the future. In the grinding concept, a PSI 500 particle size analyzer (Fig. 6) is taken as a practical example of the implementation of the unit process framework.

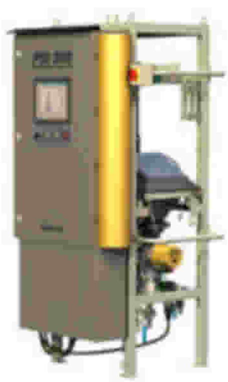

Fig 6. The PSI 500 Particle Size Analyzer.

The major process equipment improvement requirements are in operator support systems and in integration of the equipment life-time information. One of the main challenges is the efficient use of maintenance data, together with equipment operation data, in order to optimize the total circuit operation. This target implies a need for the development of equipment operational indices and data connectivity. Furthermore, knowledge integration tools during the plant life cycle are currently considered essential, as well as product data management (PDM) systems.

A wider availability of the expert services for the process equipment running is considered important. The forces driving the need for services are, for example, the greater complexity of the equipment and more sophisticated operating methods. Some of the routine services could also be offered remotely.

The grinding unit process automation framework and its implementation in a particle size analyzer are illustrated in figure 7. As presented in figure 5, the unit process automation operates between the equipment network and the process automation system. Therefore the framework contains modules for DCS connection, as well as interconnections between the systems at the same level.

The expert resources and life-cycle management are utilized by the product data management (PDM) module and remote connection module. The horizontal integration and networking also mainly includes connectivity to the maintenance systems. According to the concept of the extended product, the equipment and the circuit are included with the knowledge and intelligent properties provided by the manufacturer. In order to maintain the best possible performance of the process during the life cycle, the modules should be updateable with the latest methods and applications.

Integration of the analyzer to the grinding and flotation unit processes, and also to the remote service providers, is presented in figure 8. The networking concept contains four levels: equipment, process, plant and remote service levels. The equipment level defines which self diagnosis, data preprocessing and communication features are included. The process level contains process and equipment history databases and performance factor definitions. An example application of control performance evaluation is given in (Jämsä-Jounela, et al., 2003). The plant level defines the plant history database and plant performance factors. The management operations are also performed at this level and knowledge is accumulated. Knowledge accumulation and the expert services are located at the remote service level.

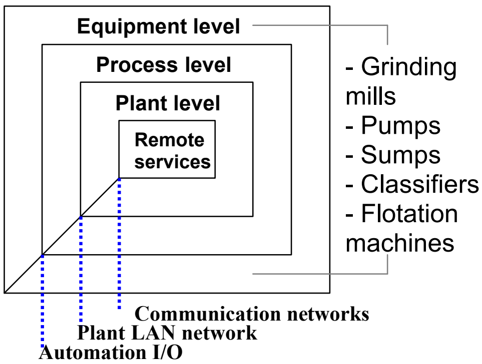

Fig. 8. Networking concept of the extended product structure for mineral processes.

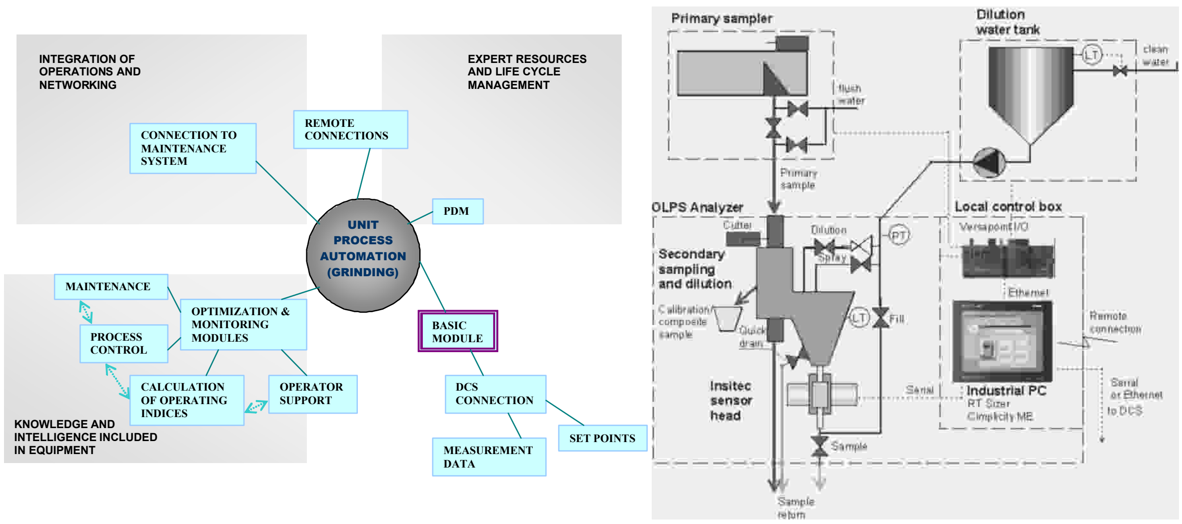

Fig. 7. A framework for unit process automation of a grinding process and its implementation in a particle size analyzer.

In the field of process analyzers, the extended product services could contain circuit performance monitoring, as well as analyzer monitoring. The particle size data make it possible to monitor, for example, grinding and classification processes. The monitoring could also be offered as a remote service. Furthermore, the grinding and flotation process monitoring and optimizing could be merged more tightly, as suggested by Edwards et al (1999).

The analyzer assay information will be more fully integrated as a part of the automation of the unit process equipment. One significant benefit in the tighter integration of the equipment and automation is the ability to exploit the unit process knowledge of the manufacturer. The remote services of the extended product will become even more considerable when plants outsource their maintenance, as has been the tendency recently.

5. CONCLUSIONS

The life-cycle management of process equipment is a multi-dimensional problem with different aspects related to the optimization, compatibility and integration of the operations. Some of the basic issues related to development of a total process management framework were presented.

The goal in developing frameworks and methods is to interconnect different data interfaces, and to gather all the information related to the machine operation during its life cycle into one embedded automation platform, and to network the information to different systems. The main advantages of this concept are cumulatively improved operation knowledge, an ability to implement efficient operator support methods, and systematic feedback to the product and unit operation designs. These will all lead to short and long term improvements in production competitiveness.

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