Smart factory,
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THE SMART FACTORY – PERVASIVE INFORMATION TECHNOLOGIES FOR MANUFACTURING MANAGEMENT

Today's manufacturing management is marked by a high degree of uncertainty and turbulent conditions. Changing customer demands and highly volatile customer orders lead to complex structures in manufacturing management. Today's information and communication technologies can help to establish networks of pervasive computing to permanently monitor and visualise the status of all manufacturing resources. The paper presents such a framework and strategies for the "agile and transparent" factory of the future.

1. INTRODUCTION

Information about manufacturing resources is a key element of production companies. This paper shows new concepts using the idea of pervasive information technologies in production systems. Decentralized, dynamic structures are designed in order to reduce down time risks [1][2]. These systems hold the advantages of distributed intelligence and therefore are able to compensate for failures in single cells. At the same time the complexity of the processes are reduced to a minimum which makes the system's management together with a modular engineering user friendly and easy to customize.

Competitive manufacturing strategies have to focus on efficient machine utilisation, reliable processes and an effective overall performance monitoring up to the fringe ranges of technological potentials. Immediate reactions to performance deviations are crucial for keeping the budget lines and to secure calculated profits ratios. For this, transparent manufacturing systems are essential which provide all kinds of data necessary to online monitor key indicators of system's performance.

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2. SMART FACTORY

A digital factory is defined by multiple elements. The first step is a full geometrical, scaleable model of the factory. In this respect the digital factory of today is a tool for ergonomic layout planning. Ideas are brought together easier and changed faster without the limitations of normal paper work. The next step from static models towards a dynamic system is the implementation of simulation modes. The so called virtual factory enables planers to optimize production facilities or to evaluate changes by bringing a defined load onto the model. This simulation process allows logistic and process optimisation at different scales. Suppliers and operators may use the same data base as engineers or consultants. The changes within the factory establish faster because more experts are able to simultaneously work together. This in return saves costs and simulation makes it possible to focus momentum onto identified root problems. A known problem for planners is the fact that the manufacturing facilities have a long life, but their configuration changes within months. The third step is the fusion of the virtual and the physical world. In this new type of factory physical models feed virtual models with field data that in return simulate changes or possible options within the production line. Even after the factories are installed, data flows back into simulation models. This makes it possible to learn from the future without manually updating input. These mechanisms will solve the problem of outdated information and data overflow by processing and storing data as close as possible to the resource and only passing relevant information forward. The consequence is a “Smart Factory” that optimizes the life cycle of the manufacturing systems by using data collecting and filtering technologies that blend into the environment.

3. TRANSPARENT PRODUCTION MANAGEMENT

To cost control a manufacturing system different data from various sources are needed. Obviously the mastery of system’s behavior requires production resources and machining data.

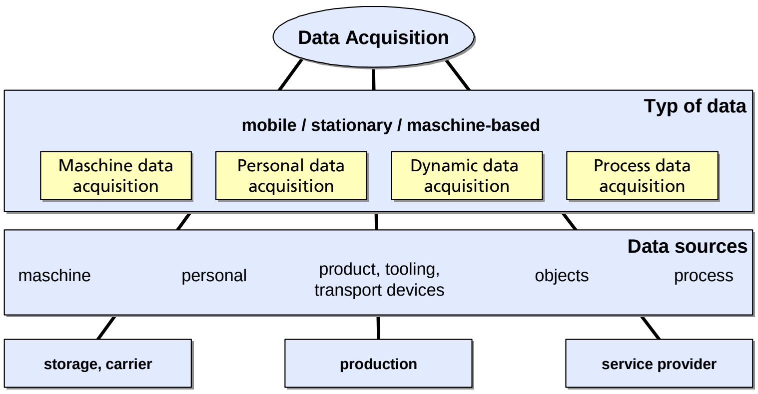

Fig. 1. Framework for manufacturing data acquisition [3]

Fig. 1 shows the key data and improved planning data for production management. [4] The different types of data have to be acquired from the manufacturing resources and if necessary from external sources. This offers the opportunity of remote machine access for data logging via internet or telephone lines. The relevant machine data can be extracted from the data flow and serve as one input for in-situ performance monitoring and forecast. Various research projects have shown that optimal logistics play an important role to avoid performance losses. A controlling system has to take these facts into account and therefore data from parts logistics have to be integrated into the supervision system.

3.1 PRESENT RESSOURCE MANAGEMENT

Short planning horizons put stress on production planning. At the same time manufacturing processes are not limited to a specific work place but a complex cooperation of several periphery systems. Therefore management of manufacturing resources (transport systems, warehouses, machines but also tools clamping fixtures measuring devices, NC-programs etc.) and the synchronisation of their usage is a central element of factories with high demands in productivity and flexibility [5][6]. Reports in literature and of company representatives often criticize an unsatisfying supply of manufacturing resources. Often equipment is missing before the manufacturing starts or resource deliveries are unpunctual. Tool inventories are not exactly known by number and kind or companies complain that the tool reservoir is too large encouraged by late resource deliveries. An economical or efficiency report of the resource management is not common or sometimes not even possible. The fate and behaviour of some resources within the manufacturing system is unknown and therefore overhead stocks are likely to be existent. For the same process numerous tools are used creating numerous results. Sometimes tools are still ordered when the production of the relevant product is already cancelled. Process specific or sometimes workpiece specific tools raise complexity of the resource management task. Against major trends of decentralised intelligence and distributed communication today's production and automation systems still use centralized structures for resource data management. Production lines and their resources are still organized over a control centre and split into task elements like logistics, production lines, human resources and quality management. The symptoms show that centralized structures however are not able to manage flexible, mobile resources and processes. In order to satisfy the requirement a new approach is necessary. Decentralized intelligent systems are able to react more efficiently to changing requirements.

3.2 IMPROVEMENT POTENTIAL OF RESOURCE MANAGEMENT IN SMART FACTORIES

As shown it is necessary to enhance present resource management toward a more flexible, efficient system. The basis problem of present solutions is a inflexible structure that has to handle a complex task without all relevant information. In order to receive reliable information about manufacturing resources, which is the first step towards a reliable management, an environment must be created that collects and delivers information as soon as it is needed, to the location where it is demanded, in the depth asked, without the restrictions of wired communication. This is a challenging task remembering that optimizations of information networks and information streams as well as quickly analysing faults and their roots will have a direct impact on future production systems their financial success. Two sorts of resources are known, immobile and mobile resources. (Fig. 2) Mobile resources can be subdivided into low and high mobility. Low mobile resources are those that do not change there position frequently but have the ability to do so if necessary. Good examples are NC-machines that are usually put into place for about 5 to 10 years. Highly mobile resources are for example handheld devices or tools. It is obvious that the mobile objects cause planning problems and are the main cause of the symptoms described in the previous chapter.

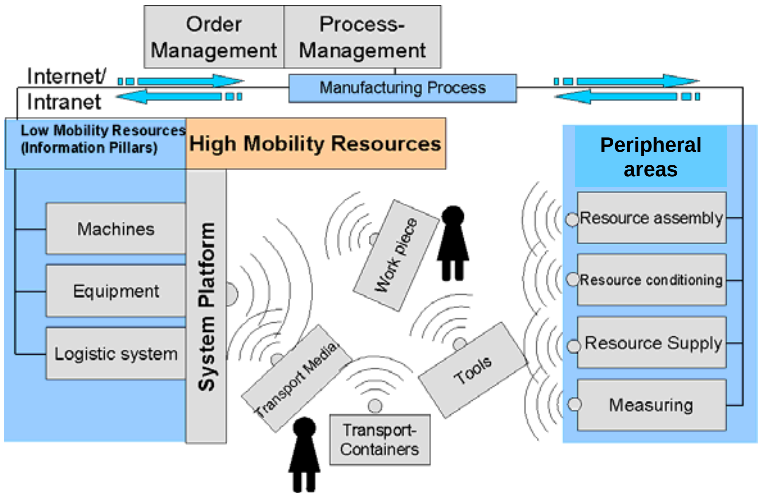

Fig. 2. “smart” resource management

They already are an important factor and their importance will rise observing the continuously increasing competition. The question is how can we cut down tool costs and raise efficiency of mobile resources. To buy a new manufacturing resource and to fully integrate it into the process needs several steps in classic productions. A request followed by a resource evaluation. Once a lack of resources is detected theoretically several reactions are possible to deal with the situation. From buying to resource rents different approaches are standard procedures with known advantages and disadvantages. In our case the resources the resource is ordered. Several forms have to be filled out before the request reaches its goal. Once the resource arrives it has to be booked into stock and finally handed out to production. This shows how reactive and linear most processes still are. In order to reach the goal of highly flexible parallel productions the reactivity has to be transformed into an active resource management. This means that data that concerns the resource flow within the company have to be used in order to simulate future demands. At the same time processes like booking can be simplified by using automatic identification and location services. Resources could then book themselves into the system automatically when they arrive and even inform the necessary persons. By automatically interacting with the booking protocols the data of the resource is refreshed within short periods of time.

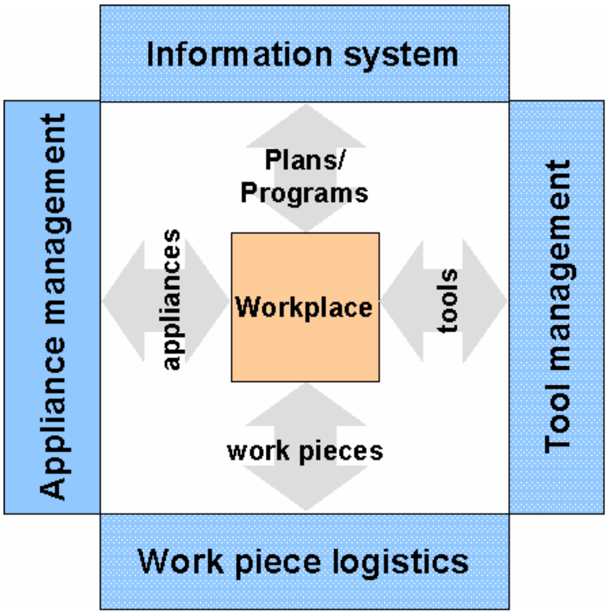

Fig. 3. Work place/ process as the centre of interest

In a smart factory technical resources and work places will be able to communicate with their environment informing it about their condition status and location (Fig. 3) [7]. This will have a direct impact on availability and stocks. Production control will have a direct interface to the resource management allowing it to take production plans into account. The centralized control dissolves into decentralized structures, autonomous modules able to store the information they created and able to transfer necessary information to partner modules over wireless connections. Now that the central structure is virtually none existent there is a lower possibility of data overflows. The modules will be able to process data into reliable information instead of trying to send all the data into a central mainframe. Of course it is not possible yet to store a high amount of information and processing power on a drill. Information pillars will be used as knots in this network. Low mobility resources like for example milling machines are already connected to the intranet, the necessary energy supply. They are already able to store and process data so they could take over the position of the described information pillars. As shown now the work place and process is the centre of production. Because the process is also able to manage itself and to give out information rather then pure data human workers are able to concentrate on further optimize the central process instead of wasting efficiency trying to organize the peripheral system or to understand data code. Information between the workplace and the supporting systems is exchanged bidirectional, which keeps problem identification and reaction times low.

4. PERSVASIVE SYSTEM SUPERVISION AND EVALUATION

4.1 SYSTEM MANAGEMENT

At production level, this means implementing the conditions specified and producing the services efficiently. To do this, a controlling system is needed which reaches right down to the individual production contract and which records the processes and resources required for the manufacture of the product at the same time. By classifying a task according to the aspects of product, process and resources, the production process can thus be dismantled in a modular way and linked to the corresponding process costs. As well as being able to supply a quotation or pre-calculation quickly and efficiently, the process-orientated production structure also allows for automated work preparation support (piece lists, the compilation of work plans). In order to be able to utilize sound data material, detailed production data from production data acquisition (PDA) or machine data acquisition (MDA) is required. [8] [9]

This planned data is then compared continuously with the real production data – sometimes even on-line. In this way, deviations can be immediately recognized and profitability (or quality, deadlines, etc.) be assured by taking appropriate measures promptly. Today's PDA and MDA systems are already capable of providing highly-detailed analyses of production events. In the PDA process, data is fundamentally classified into the following types: order data, machine data, material data, personnel data and quality data. Subsequent to the increased use of computer-assisted systems for acquiring and processing production data, a wide range of data is available for analysis purposes. This permits planning data to be compared with the actual execution of the order and to be updated accordingly. At the same time, by linking the actual data to the resources used and the corresponding costs incurred, true production costs are disclosed. The equipment or production order can therefore be controlled on-line.

4.2 SYSTEM EVALUATION

By monitoring the actual process statuses (process monitoring) and compressing and comparing real data with planned data (process control), process quality can be evaluated. Process information systems provide information support for this task. At the moment, the main challenges involved here include increasing process orientation and implementing the necessary organizational and information tasks.

The relevant processes contributing largely towards the result need to be selected from the wide range of company processes involved. In order to obtain sound process control information, the real data occurring needs to be compared with the planned data. (Fig. 4) Process information systems are much more than process cost calculation systems assisted by data-processing; this is because data mainly concerned with value is determined rather than quantifiable data such as cycle times or the time factor of a process organizational unit. [4]

The permanent machine data acquisition also allows to evaluate the overall equipment effectiveness (OEE). This measurement has its origin in the philosophy of total productive management. The OEE measures all losses occurring during machine operation. All sources of losses are accumulated into one %factor, the OEE factor. This number ranges from 0 to 1 meaning that a factor of 1 (or 100%) describes the optimal machine performance. The OEE factor consists of six major loss categories.

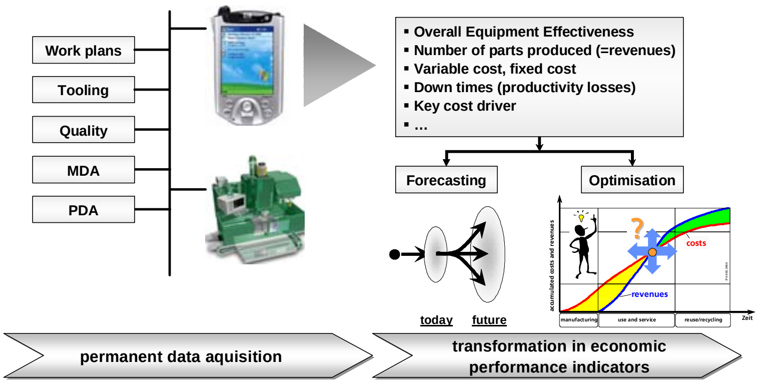

Fig. 4. Economic Machine performance control

The data which are necessary to analyse and aggregate this categories can mainly be acquired from machine and production operation. Therefore it is possible to analyse and optimise the machine cost by these control systems. The losses identified by the OEE analysis can be interpreted as lost profits (or add. cost, “opportunity cost”) because for the inappropriate machine operation parts cannot be sold and additional labour and material cost come up. The equipment effectiveness losses which are measured can be expressed as a coefficient and transformed into economical values by linking them to resource process cost rates. The expression of this “performance loss” usually represents an enormous and often-underestimated value-adding potential in production which the Institute for Industrial Manufacturing and Management (IFF) and the Fraunhofer IPA, Stuttgart, in Germany can demonstrate. The retrograde analysis and cumulated analysis of production data also show up the main cost drivers and “expensive” work steps. This knowledge is useful for reorganization planning, re-engineering and long-term technology planning purposes. [10]

6. SUMMARY

This paper outlines the vision of a smart factory and outlines a possible scenario. The proposed solution takes the idea of ubiquitous computing into the industrial sector. Combined with ad-hoc networking a decentralized, flexible and active resource management is achieved. Other scenarios like logistics and business process simulations are mentioned to show the enormous potential of this idea to the manufacturing industry. Using these enabling technologies will bring us toward a new kind of factory that operates intelligently within new dimensions. To do so sensors have to communicate and a sensor network has to be achieved [11]. By knowing the exact state of the environment at any given time, a dynamic resource adaptation is possible which reduces downtime. After talking about a possible scenario and outlining the advantages of the new structure enabling technologies are discussed. These technologies show the trend towards ubiquitous computing and the speed of development new organisational and technical concepts have to take into account.

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