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One-Product-Integrated-Manufacturing

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Abstract

A new organisational frame for manufacturing system integrated over one-product manufacturing is proposed. Integration of a one-product enterprise is realised over a set of independent cells domain. They are connected by the wide-area-network using multimedia telematic technology to provide negotiation in real time. This characteristic provides the possibility to constitute an one-product factory from elements that are localised globally especially for the manufacturing operations which are information based. In this way a concept of a global manufacturing is applied. The life time of a one-product factory/enterprise corresponds at most to a product life time. This organisation form is called One-Product-Integrated-Manufacturing (OPIM) System. The system is characterised by the factory models flowing through the product. OPIM System is a physical implementation of a virtual factory.

Keywords

One-Product-Integrated-Manufacturing, virtual factory, distributed manufacturing system, global manufacturing, factory models flow through product

1 INTRODUCTION

New manufacturing system concepts should provide a start in the XXI century race with qualitative better performances. Characteristics for the new manufacturing system concept could be derived from analysis of the manufacturing systems space representation. Considering this representation, directions of existing manufacturing system concepts improvements start from **Computer Integrated Manufacturing** (**CIM**) concept, placed in the middle of the manufacturing systems space, and tend to spread in all directions, achieving high flexibility. This strategy leads to a manufacturing system able to:

1. Manufacture from 1 to 1000 products simultaneously,
2. Accommodate lot sizes from 1 to 1 000 000

covering entire space, figure 1. But, to satisfy 1. and 2. efficiently, the manufacturing system must be highly reconfigurable leading to the additional requirement:

3. The new generation manufacturing system should reconfigure for a new product within 1 second, Kim (1990).

L. Camarinha-Matos et al. (eds.), *Balanced Automation Systems*
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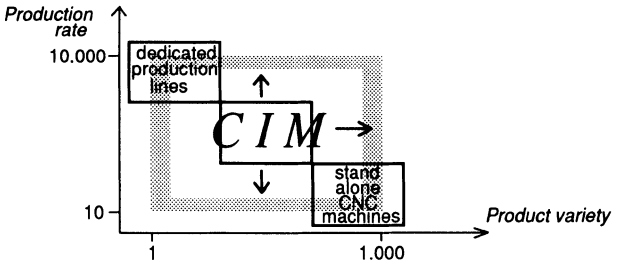

Figure 1 CIM concept, placed in the middle of the manufacturing systems space, tends to spread in all directions, Kim (1990),.

2 A MULTI-PRODUCT-INTEGRATED-MANUFACTURING SYSTEM - THE EXISTING CONCEPT

The strategy of spreading the CIM concept over the entire manufacturing systems space, has some limitations.

First, although systems such as PPC/CAD/CAPP/CAM/FMS/FAS are included in a CIM system this doesn't mean that they are automated. Only aspects of manipulation and memorisation of related objects are automated ("Computer Aided" attribute) but the design functions are still in the human domain. This is a very serious limitation in achieving the target manufacturing system of the future. It is accepted that the aspect of design automation is solvable by introducing artificial intelligence concept in CIM systems. In this way we come about to the concept of **Intelligent Manufacturing Systems (IMS)**.

Second, in CIM and IMS concepts the hardware and software flexibility is an important issue, but study on organisational structures is not emphasised. However, new studies on organisational structures present models which we understand to accommodate concepts like CIM and IMS.

A list of manufacturing system concepts including organisational aspects is given bellow.

- **One-of-a-Kind Production (OKP) Systems** , Rolstadas (1991), Mertins et al. (1992), Vepsalainen (1990).
- **Global manufacturing** , Mitsuishi et al. (1992), Lalande (1992), Carlson et al. (1992), O'connor et al. (1990), Horgan (1990).
- **The next generation of FMS systems based on metamorphic machines** , Ito (1992), Yoshikawa (1984).
- **A fractal factory and Holonic manufacturing system** , Warnecke (1994), Winkler (1994),
- **A virtual factory** , Kim (1990), Staffend (1992).

All these sophisticated, highly performing models, are based on the paradigm that a manufacturing system processes products.

We will call this paradigm a **Multi Product Manufacturing System**, figure 2.

The figure emphasises the fact that multi-product integrated manufacturing system is characterised by the **flow of products** through it.

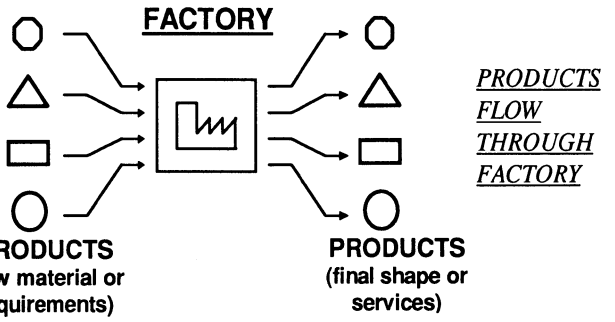

Figure 2 Multi-Product Manufacturing : the *flow of products* through a factory.

All models mentioned above, are **always based on the existing hardware structure of one company**. But, using the system for a variety of products means loosing some technical efficiency because it is clear that each particular machine can be used with maximum efficiency just for one type of products which employs the maximum capability of the machine, figure 3a.

The conclusion is that, in any case, with a fixed hardware structure a company cannot ever achieve maximum efficiency. This phenomena is the main reason for introduction of "metamorphic machines" capable to adapt to any particular product. It is not clear if and how could metamorphic machine design principles be applied to organisational design.

3 ONE-PRODUCT-INTEGRATED-MANUFACTURING SYSTEM (OPIM) - THE FUTURE CONCEPT

Multi-product-manufacturing systems are conceived for a variety of products. This means loosing some technical efficiency of machines when compared to a dedicated system. Full performance facility is possible through a manufacturing system for a single product, figure 3a. Thus, we could think of establishing a factory/enterprise just for a particular product, and for a number of products we would need at least equal number of factories/enterprises, figure 3b.

3.1 Designing / integration of the OPIM system

Under the One-Product-Integrated-Manufacturing (OPIM) concept a new manufacturing system structure is conceived for every new product. The design and manufacturing processes for a product should be decomposed in a sequence of particular tasks. The most suitable resources for each task should be selected. Searching for the resources for task realisation means selecting the structure elements.

The domain for resources selection is the set of all cells, Putnik (1995), (machine tools, transportation devices, computers, manufacturing cells) which can realise the necessary

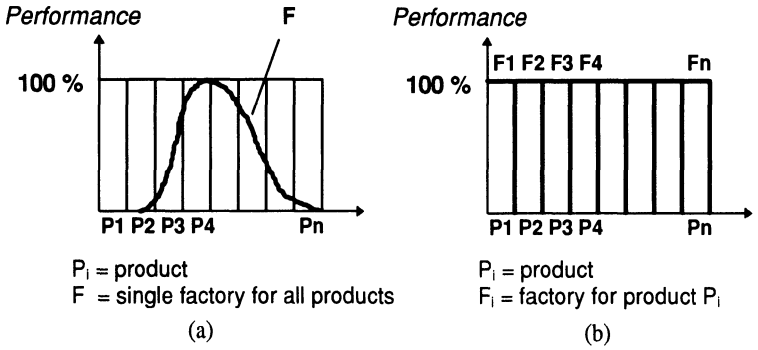

Figure 3 Facility performance for (a) multi-product manufacturing and (b) OPIM system

manufacturing functions, connected by public communications network, using multimedia telematic technologies.. To provide optimal choice the domain, the "market" of cells, candidates, should be as large as possible. If the domain is limited to the set of machines within an existing factory then the concept will be reduced to a One-of-a-Kind production system or to a virtual factory.

The complexity of OPIM system design can be illustrated as follows. Let the domain for OPIM system design be represented as a connected graph (OPIM systems building blocks, cells, are connected by public communication network). If there exist a manufacturing system structure which can be defined over the available domain it means that the design task can be reduced to a task of finding a subgraph, of the domain graph, which satisfies given requirements for manufacturing. This task is hard, belongs to NP class, because a set of N manufacturing system elements, defines 2^N manufacturing system elements subsets, the power set, for building more complex structures. This means that the OPIM system design must be based on AI based technologies for decision making. The lattice of the refereed power set is shown in the figure 4. as a OPIM system design/integration domain.

The design process should be performed automatically to achieve *a real time reconfiguration* and a good solution. All elements of domain set and all new designed elements/cells should have a formal representation (Putnik (1995)) in a common knowledge base. The OPIM system design process is a process of defining an interpretation, instance, of a general model of a manufacturing system. The design process is realised through negotiation between the leading company, which initiates the OPIM process, and the number of cells, candidates, for realisation of manufacturing tasks, including design, planning and control and manufacturing. During the design process there is a number of virtual factories which forms the solution space. Based on a defined performance criteria, the initiator selects the optimal factory structure. We could say that we have a flow of virtual factories through the product.

We will call this paradigm a **One-Product-Integrated-Manufacturing System** concept. The OPIM system is characterised by the **flow of a factories** through a product, figure 5. This is the **inverse model** of the multi-product-manufacturing system.

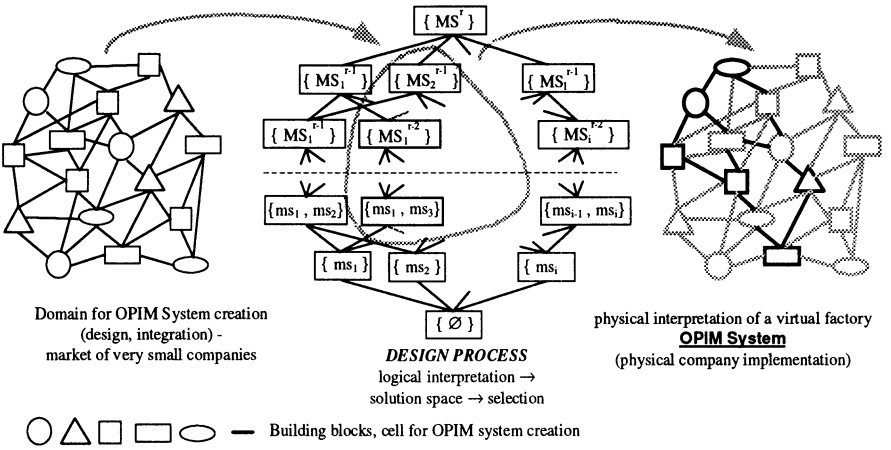

Figure 4 The lattice of the manufacturing system elements power set as a OPIM system design / integration domain.

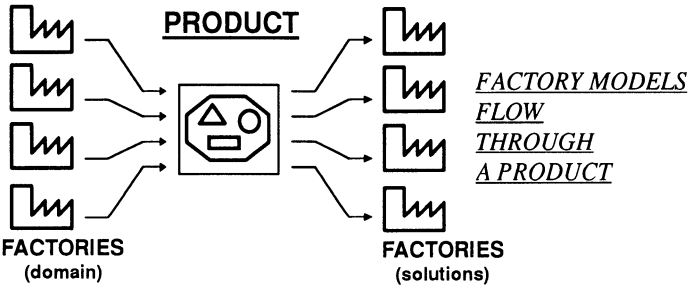

Figure 5 OPIM system : the *flow of factories* through a product.

3.2 Some characteristics of the OPIM system

A list of some characteristics of the OPIM organisation form is given :

- The optimal structure is built up from primitive cell, single machines. Each cell is specialised in one type of service (design, planning, management and manufacturing) for one type of product. The resulting physical OPIM system should be the best performing system for the product under the available manufacturing cell market.
- All design, planning and management functions are information based and independent of distances between the processing units. The processing units can be located at any point of the world if they are connected by the communication network. This is a pure application of a global manufacturing concept.
- The integrated OPIM system is essentially distributed manufacturing system.

- OPIM System is a physical implementation of a virtual factory.
- The flexibility of the OPIM concept is in the design stage. The OPIM system itself is not flexible. It is a system dedicated to one specific product.

4 OPIM SYSTEM IN A SPACE OF MANUFACTURING SYSTEMS MODELS

Using a formal, rigorous definition of manufacturing it is possible to specify a manufacturing systems definition space. The richer the space is, the better the chances are for qualitative development of manufacturing systems. Through specification of the manufacturing systems definition space it is possible to build a rigorous taxonomy of manufacturing systems/models. The manufacturing systems space, defined in chapter 1, figure 1, which gives emphasis to flexibility, should be enlarged by new aspects.

The manufacturing systems definition space will be called **"the manufacturing systems reference model"**. A basic reference model can be defined in a three-dimensional space:

1. **degree of integration** (structure and functionality). Integration as a key issue for developing/designing the "factory-of-the-future" model. The concept of CIM is a manufacturing system concept defined at a high degree of Computer-Aided integration.
2. **decision making** . Intelligence , with a decision making technologies as a key issue.
3. **organisation** . Organisational aspects of the target manufacturing system.

In this reference model each of the manufacturing system concepts mentioned above, section 2. and also OPIM system, are defined by triples, points in a three-dimensional space, figure 6.

Integration in the OPIM system is defined over a globally distributed domain. The high degree of integration is based primarily on WAN technologies. This concept is expressed through the concept of *'Global Manufacturing'* with the additional attribute *'Integrated'*. The OPIM system implementation and utilisation is design intensive (belonging to hard problems - NP class) for which we need in any case nondeterministic algorithms, that is, *intelligence*, for achieving good solutions. Finally, the OPIM system itself is a *particular organisational frame.* Thus,

One-Product-Integrated-Manufacturing System is defined by a triple:

('Global Integrated Manufacturing', 'Intelligent Systems', 'OPIM Organisation Framework')

5 CONCLUSION

Users of OPIM system are any size company, very small, SME and large companies, or any person which is self-employed offering and requiring teleservices on manufacturing activities.

- Companies can benefit from OPIM in two ways : 1) by strengthening competitiveness through access to competitive resources, services and knowledge (which is a high value-

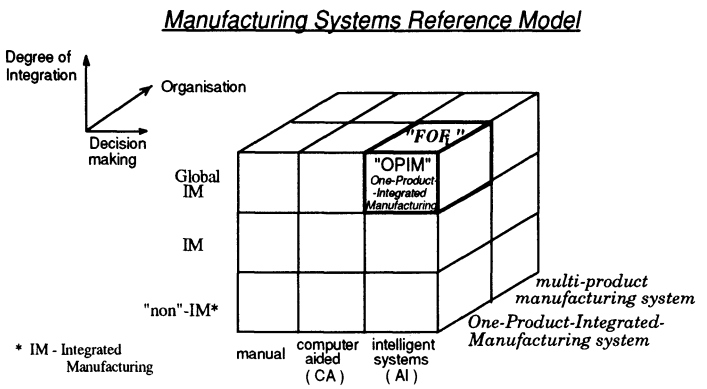

Figure 6 OPIM system in a space of manufacturing system models.

aided resource) provided by teleservices and 2) by dynamic business process re-engineering leading to new products, services and business supported by a networked underlying universe of resource entities. Further advantages can also be envisaged, for large companies, through decentralisation and business distribution through competitive locations.

- Self-employed people can benefit from OPIM through integration and co-operation with SME and large companies for competitive development of complex processes, products, services and business. Competitive base, in this case, is, for example, avoidance of travelling and transportation cost, use of free and low-cost facilities (own home) and independence of distance.
- OPIM can also offer lower prices, high quality of a products and competitiveness, and high flexibility for creating manufacturing systems through large number of small companies which can include one machine and one self-employed person.

A number of researching issues are imposed. We list some :

- Formal specification and design of the OPIM system, the intelligence for OPIM, transformation of information Company to Knowledge Company, communication based on multimedia telematic technology and related problems, task-resources allocation management of the OPIM system, distributed and real-time CAD/CAPP/CAM/PPC applications, economy of the OPIM system, legal aspect of the OPIM system and intellectual property issues.

Other topics related with OPIM model are, for example, "architectures for systems integration, federated architectures, Computer Integrated Business", integration of self-employment in global economy "independently of their geographical location".

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7 BIOGRAPHIES

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