Digital Manufacturing in the global Era

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The global era of manufacturing is going on. Digital Manufacturing is one of the core strategies of the European Manufuture vision and strategic agenda towards the knowledge based production. It is driven by the application and standardization of information- and communication-technologies and the increasing demand for the efficiency of operations in global networks. The environment of manufacturing is turbulent and requires permanent adaptation of the manufacturing systems. Manufacturing Engineering covers wide scales from networks to processes and from real time to long term operations. The tools of future engineering and management of manufacturing are digital and distributed. Strategic aspects and the potential and needs of research and development are main positions of the presentation.

1. INTRODUCTION

Manufacturing is the backbone of our economy. In 230.000 companies are more than 27 Million people employed. The total added value of these industries is about € 1.300 Billion in Europe. It has a long tradition and its role is adding value for the economies and their prosperity. But now there is a strong change caused by globalisation and internal changes of technologies.
More than 80 years ago Taylor formulated the paradigms of scientific based manufacturing: "Analysing the manufacturing work on elementary processes with scientific based methodologies gives benefits to the economic efficiency of companies and their workers"/1/. The so called "Taylorism" is still today the dominant paradigm of manufacturing in practice. The methodologies changed and computers are used in nearly all processes. Manufacturing is on the way to a knowledge-based and digital era.

2. DRIVING FORCES and CHALLENGES

Global networks of communication and the diffusion process of electronics and information systems characterise the environment, in which peoples live, business and manufacturing is done. The world of manufacturing of this century is a networking information world - inside and outside of enterprises and linked to all participants of markets.

2.1 Migration of production and consumption

The fast and global transfer of information and open markets is beside of economic aspects the main driver of changing the global structure of manufacturing.
Comparing manufacturing of the last decades of the 20th Century to the actual situation - we have now - it is evident that new requirements are driving forces for the global changes of the manufacturing area:

- Migration of production and consumption of industrial products to developing regions,
- Turbulent environment and influencing factors – only robust and transformable enterprises survive,
- Global networking in engineering and manufacturing on a global quality level.

The migration of production and consumption towards global manufacturing and especially to growing economies accelerated. Fig. 1 shows the general development from the Triade to the developing countries.
The migration creates value and prosperity and in the origins unemployment. In the technical view we notice the equalisation of technologies and quality and a new challenge for acceleration of innovation.
Innovation for adding value may solve unemployment problems by generation of new products and processes. Innovation in this century is driven by basic knowledge and can transform the manufacturing towards a knowledge based new Taylorism - using the digital manufacturing systems /2/.

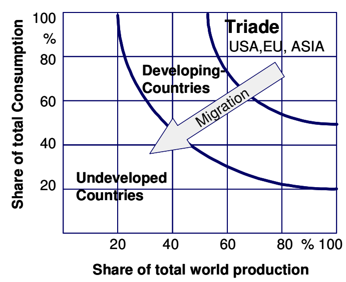

Figure 1 - Production and Consumption of technical Products

2.2 Objectives of Manufacturing Development

New technologies and the adaptivity of the manufacturing structures are challenges for our future. The EU-Initiative Manufuture demands as objectives of future development towards 2020:

Competitiveness of European manufacturing industries
- to survive in the turbulent economic environment
- to compensate migration and consumption of technologies
- to have more and better jobs
- to stabilise economic results (growth)
- to ensure welfare and social standards of living

Leadership in manufacturing technologies
- to support innovative products and platforms
- to lead manufacturing with global standards
- to guarantee human and social standards of work

Environmental friendly products and manufacturing
- to reduce the environmental losses
- to change the consumption of limited resources
- to maximise the benefits of each product in the life cycle.

All of these objectives are focussed on the innovation of the manufacturing industries. They require an innovation culture inside of companies to fast implementation and permanent transformation of the manufacturing structures.

2.3 Adapting to changes in a turbulent environment

Flexibility can give companies enormous advantages in custommer and market orientated innovation, as the structures of present companies are usually only adaptable up to a certain extent. The external and internal factors of manufacturing are changing permanently and require the dynamic change in operations, organization and structure as it is shown in Figure 2. The problems are associated with time-related transformation when altering structures concerning property and possessions, personal resources and established methods in the information system. Adaptability has a temporal aspect. It is not a question of whether the management is prepared to change: this is being strived by permanently by all responsible persons in management. The crucial factor is the time required and expense involved when carrying out an alteration /3, 4, 6/.

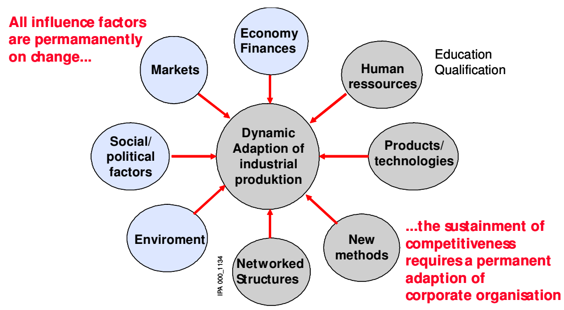

Figure 2 - Turbulent Influences - Dynamic adaptation of structures

3. DIGITAL MANUFACTURING for INTELLIGENT PRODUCTION

3.1 European Manufacturing Platform “Manufuture” and global Cooperation

European Technology Platforms are a newly introduced concept that aims to bring together all interested stakeholders to develop a long-term shared vision, create roadmaps, secure long-term financing and realise a coherent approach to governance. The Technology Platform specifically designed for the manufacturing will mobilise and concentrate a critical mass of research and innovation effort in a mission-oriented plan with actions that will provide practical benefits to enterprises actively operating in the sector.

The MANUFUTURE Initiative of the EU is oriented to a Vision of manufacturing in 2020. Just like Taylors view the visions base are science and technology implemented in holistic networking manufacturing and managed towards sustainability and welfare. The MANUFUTURE Initiative has 4 Levels: Global, European, national and regional.

Fig. 3 shows the main and strategic orientations of Manufuture - following a CIRP Model for the new age of manufacturing. Its focuses are business models, advanced industrial engineering and emergent technologies for High Adding Value (Fig.3). The knowledge generated by research has to be transferred to application by efficient R&D and education. All of these pillars take the full availability of IT and networked manufacturing into account. So that it can be stated, that this initiative is oriented to the digital manufacturing of the future.

Product Engineering, Production processes and the management of industrial enterprises need a common base for realising the goals of European Manufacturing and maximise the synergy towards the 2020 Vision. This frame indicates the industrial sectors on one side and the need of research in Engineering, Production Processes and enterprise management.

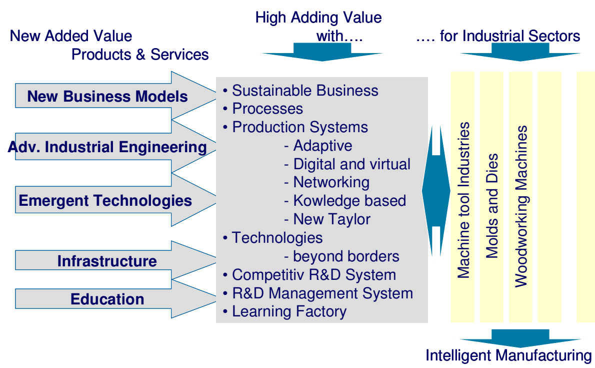

Figure 3 - EU Manufuture Strategic Research /11/

3.2 Paradigms for Manufacturing

The following theses are contributions to the manufacturing vision and development of research on global level.

Life Cycle Orientation

The new paradigm of manufacturing is oriented to the optimization and value creation of products in their whole life. This assumes the understanding of the requirements and usage of products (customisation), the manufacturing, product-near services and recycling. Basic information and communication technologies are used to follow products over their life from engineering to the end of life. This understanding allows Manufacturers to follow each product in its life and to maximise the benefits of each product.

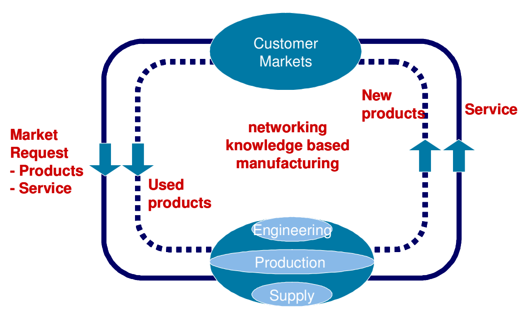

Figure 4 - Life Cycle Orientation

The factors of success of manufacturing industries are mainly based on high diversity and high personnel skill in all levels. The new developments will change the structure of future work in the life cycle of technical products.

Sustainable Business

To manage and to optimise the life cycle it is necessary to develop new business models. Business models which activate and add value have to transform the conventional relationship between manufacturers and users. Sustainable business for life Cycle takes into account the responsibility for environment and consumption of natural resources as well as social standards of work.

There is even another aspect of sustainable business: To maximise the profit more and more companies operate in short business dimensions and invest only minimum in R&D. Many of them see the responsibility of R&D by governments or suppliers. Business models of the future take into account even long term strategic R&D for manufacturing as part of the sustainable businesss /10/.

Global networking

Manufacturing processes used to be linked together in a line; today these processes are usually part of complex manufacturing networks that span across multiple companies and countries. By using manufacturing networks, it becomes possible to integrate manufacturing processes into dynamic, cooperative manufacturing and value-added networks and also to remove them from those networks if necessary.

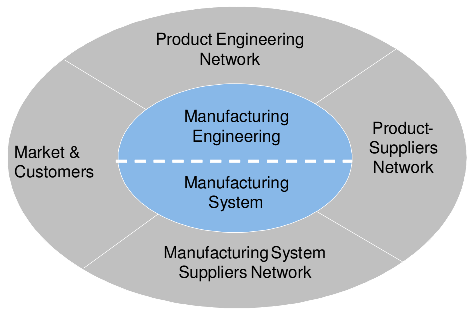

Figure 5 - Networking in Manufacturing: Activating Potentials of Synergy

Efficient networking requires standards and management systems for the networking in engineering and logistics based on global communication standards. In the future the flow of materials from origin to the end of life has to be documented.

Emergent Technologies and Manufacturing Engineering

Manufacturing technologies are in permanent development towards new dimensions of efficiency and to overcome existing technical limits. The common objectives are to summarize as to overcome limits in manufacturing by the activation of theoretical potentials of technologies to save time, materials and energy with innovative solutions.

Fast activation of technological potentials in manufacturing technologies is a prerequisite to achieve advantages in the competition of manufacturing industries and users in a broad field of industries. Main potentials to overcome existing limits are:

- High Performance technical processes (Time, Precision, Cost)
- reduction of energy and material consumption
- reduction of time and increase of utilization of machines
- reduction of waste and emissions (clean manufacturing)
- zero defect manufacturing

There are diverse new technologies for manufacturing, which promise high potentials to overcome existing limits.

Theoretical boarders are defined by natural (physical, chemical, biological) laws. The degree of utilization caused by the technical solutions, the influencing factors and the uncertainness of the processes can be increased by research and experiments.

The knowledge about the processes is the main success factor towards higher efficiency.
Beside of the traditional goals like time, cost and quality are some with higher future impact like the reduction of energy consumption and material. Another interesting aspect is the efficiency of the integration of functionalities in parts and components like it seems to be possible by surface technologies. And last but not least the methodology is a backbone of the economic efficiency.
Technological limits of processes are not reached. High quality, zero defects, high precision and high productivity high reliability of complex systems are to realise by overcoming existing limits of technologies. The goals are to reach by activating the potentials of materials, processes and cognition. The basic understanding of processes and the evaluation of critical areas can activate potential to a high level of manufacturing. This includes the manufacturing of low value parts and components sand high end product.
Manufacturing Engineering itself is the key-technology for innovative manufacturing. Engineers work in digital and virtual environment. The engineers need high developed tools like CAD/CAM, digital products and digital manufacturing. Development and Innovation of industrial products and processes is experience oriented. Experiments and experiences are the basics for reliability. In the knowledge-based industry, the "costs of experience" – loss of productivity and time – can be reduced by modelling of all manufacturing processes.

4. NEW TAYLOR INTEGRATED IN DIGITAL MANUFACTURING

Taylor defined the basic paradigm for manufacturing management more than 80 years ago. The tayloristic organisation characterises the organisation model of nearly all manufacturing processes and systems. The Taylorism divides work for humans based on elementary processes. Work of humans is planed in detail by usage of basic methodologies like MTM or REFA. Global operating companies in the automotive and other sectors use this methodology to calculate, to compare and to standardise processes world wide.
This methodology is contradictory to the paradigm of a socio technical system following knowledge based manufacturing, manufacturing in networks or principles of self-organisation and self-optimisation. Even the integration of knowledge into machines and systems is not to combine with detailed process planning for human work. So that manufacturers need a new type of Taylorism, which takes into account dynamic change and adaptation, the specific human skill and the requirements of cooperation in networks. A new European standard of manufacturing takes into account the social culture of regions.

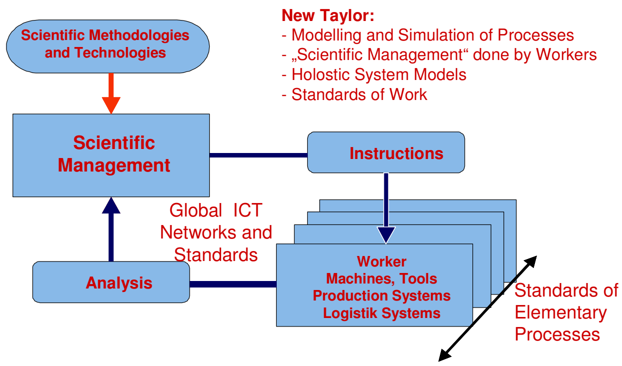

Figure 6 - Taylor and Production Systems /1/

The factors accounting for the success of manufacturing industries are mainly related to the great diversity and skills of personnel at all levels. Harnessing these abilities in the factories of the future will be vital to the economies. It will be essential to adapt the structures as quickly as possible, aided by research into all aspects of manufacturing. Rapid evaluation of change under practical conditions, monitoring the success in meeting the demands of markets, and exchanging knowledge are the keys to growth.

4.1 Innovative Manufacturing – adaptation of resources and processes

Experts discussed the reliability and the potential of new manufacturing concepts, which are based on the integration of new technologies in products and their realisation in the production area.

Intelligent Manufacturings vision are holistic systems, operating in paramer fields of high performance and managed by high skilled workers. They can be adapted by plug and produce and are linked in a digital and virtual engineering and management-IT. Some aspects of this vision are explained now.

Adaptive manufacturing recombines new and innovative processes, uses intelligent combinations and flexible configuration of products and manufacturing systems to overcome existing process limitations, and transfers manufacturing know-how using completely new themes or manufacturing-related themes.

- Adaptive manufacturing takes into account the engineering and manufacturing of functional or (adaptive) materials and intelligent manufacturing technologies.
- Adaptive Manufacturing includes the field of automation and robotics. Robots as assistants of humans, hybrid assembly, service robots.
- Adaptive manufacturing includes new solutions of automation by integration of new methods of cognitive information processing, signal processing and production control by high speed information and communication systems.

4.2 Factories are Products – adapted by Manufacturing Engineering in a digital Environment

Factories are complex and long life products which have to be adapted to the needs of markets, production programs and technologies.
For the adaptation of the resources and the optimisation in early phases companies need a new and advanced competence in manufacturing engineering which operates which operates in a digital envoronment and uses tools to adapt the ressources and processes. There are 7 layers of structure, which have to be adapted in planning processes. All of them are on permanent change /3,6/.

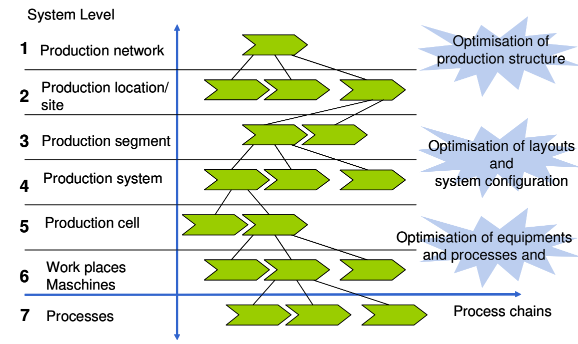

Figure 7 - Factories are products

The basis of integrated manufacturing systems is a system theory concept which permits the modeling of complex technical systems. Figure 7 shows a fundamental concept for depicting complex technical and organizational processes which seems to be suitable for portraying assembly systems. The system is made up of separate elements interrelated with one another. In an assembly system, these elements may be workplaces or other technical equipment. Interrelations are created as a result of material and infor-mation flows. A single element of the assembly system, e.g. an assembly workplace, may be a sub-system which is in turn composed of further elements /8,9/. It already becomes clear at this point that cooperation mechanisms and interfaces are a decisive feature of configurability. Using modern information and control technology, practically all elements can be linked with one another.

4.3 Advanced Manufacturing Engineering

Alteration processes to manufacturing systems are planned on an elementary basis. For example, alterations carried out on a construction lead directly to alterations in processes and documents. For the employee executing operations or for the machines, this leads to alterations in such elementary processes as movement, position or function. This also affects digital tools and the fitting and ergonomic

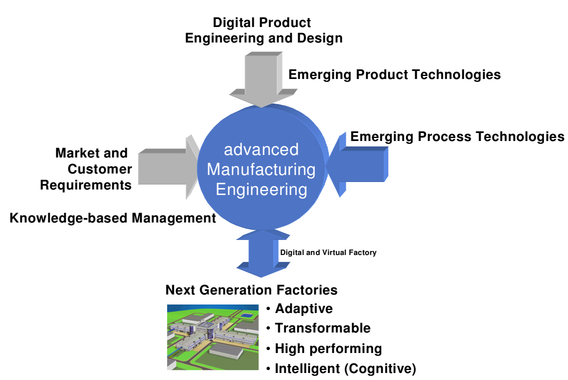

Figure 8 - Advanced Manufacturing Engineering

design of individual work stations. The corresponding superior level has the function of management and optimization.
Digital manufacturing uses a wide range of engineering and planning tools, software, and information and communication technologies to integrate new technologies into manufacturing processes as quickly and efficiently as possible /5,12,13/. Main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing taking into account the configurability of systems.
Digital manufacturing is the most important technology of the future. Digital Manufacturing needs:
- distributed data management
- tools for process engineering
- tools for presentation and graphic interfaces
- participative, collaborative and networked engineering
- interfaces to the reality

Starting with the digital picture of the factory/manufacturing and by deploying the *virtual manufacturing technologies* consisting of simulation tools and specific applications/systems, components of the aIE as well, the planners deal with the factory and manufacturing processes in their dynamicity, by having the reflection of the "as is" and state in the future "to be", the so named in our approach the *virtual factory/manufacturing*.
Engineering is a key technology. In the German manufacturing industry about 16% of the employees are engineers. They need tools for efficient work, which allows the fastening of the engineering processes and simultaneous work. Digital and virtual manufacturing is able to support manufacturers work, when this tools are near reality and linked to manufacturing as it is.

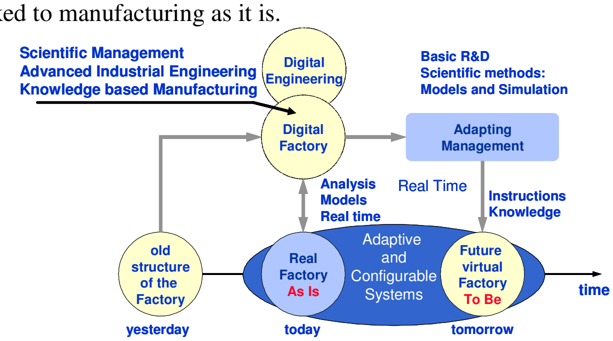

Figure 9 - Digital Manufacturing

R&D is driven by the vision of fully digital engineering and multiscale modelling the dynamic behaviour of products in the whole life cycle. By this way it seems to be possible to activate potentials in the utilisation to optimise the life time and to reduce the environmental pollution. At present, the developmental activities associated with the digital factory/manufacturing focuses on the planning of factories, production plants, new logistic systems, and of the manufacturing processes. Two advanced digital factory/manufacturing concepts are currently offered by Delmia and Tecnomatix: a few solutions from other companies are also available on the market.

These are based on a similar concept: the various software tools are mutually networked by a central data management system which constitutes the core of the integrated solutions incorporated in the product spectrum of the respective software supplier. The object of the endeavour is to ensure that all planning results are always completely up to-date and are available to the authorised users at all times. With these concepts and by using a large spectrum of simulation application/systems a virtual and scalable system constitutes the platform for high-end visualisation of the planning results and thus facilitates interdisciplinary communication among various experts despite differences in specialised terminology.

4.3 The real time Factory

Everyone knows that intelligent manufacturing systems can also be linked up to communications technology networks to assure real-time adaptation. In the future new technologies like RFID, MES, Wireless, Grid Computing and others make the vision of a real time factory or Smart factory.
From here, it is possible to proceed to networks, factories, manufacturing segments and systems intergrated in a ubiquitous information supply. We call it "Smart Factories". As a result of these developments, value-adding structures are changing in companies manufacturing and using holistic production systems. This opens up new potentials for manufacturers and users alike. The machines and equipment delivered by them remain in information technology network for service reasons, for monitoring operation status (tele-presence) and for technical consulting purposes when reconditioning and optimizing operations.

5. SUMMARY

This presentation is based on the challenges of global manufacturing and driving forces. The global era of manufacturing is hardly influenced by economic and technological factors to increase dynamic innovation and adaptation to the turbulent environment. Digital manufacturing is a key for adaptation and based on modern tools and techniques for engineering, control, supervision and management in a network. The vision of manufacturing toward Manufacturing of the Future has been formulated in the European Manufacturing Platform (Manufuture).
Taking into account the dynamics of markets and innovation the industrial engineering has a key role in the fast adaptation and complexity when factories are seen as scalable products. Optimisation of systems, data management and knowledge are new challenges for engineers and their work. It will be done in a digital world linked by global information systems. This is the new era of manufacturing – the digital manufacturing.

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