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Reconfigurable Manufacturing Systems – the Next Generation

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Abstract

ICTCM Research Center from Dunărea de Jos University is suggesting a new approach for this general concept, in order to obtain a good reaction of the industrial environment represented by investment to integrate the concept in the industry. This paper is presenting basic features of the concept of reconfigurable manufacturing systems, as was developed in ITCM Research Center.
Keywords: *reconfigurable manufacturing system.*

1. Introduction

Nowadays, companies building manufacturing machines must face fast changes happening on technical, commercial and economical field. These evolutions emerging are the following:

- economy globalization, with the consequence the emphasis of competition;
- individualization of needs, what means products customization;
- capital dynamics, generating high requirements concerning investment efficiency;
- the high versatility of small companies, ready to a fast adapt to economy.

These evolutions implies a new economic balance between, economy, technology and society. Its bound is based on company capacity for a fast reaction with minimum investment, not only to market new requirements, but also the dynamics of these requirements, described by:

- high frequency of introducing the new products;
- increasing products variety along with reducing of orders volume;
- changing concerning governments legislation (for instance those connected to environment and product safety);
-changing concerning technologies used in manufacturing.

At the time, the companies responses to these changes are based on the idea to extend some of the attributes of classic manufacturing system witch define reconfigurability. It is proposed a new peculiar manufacturing system, called reconfigurable manufacturing system, defined with six key features: i) universal, defining the ability to have various functionality role, the main Selection criteria is the cinematic (movement type, rotation or translation that module is executing) ii) convertibility, meaning the modality of changing its functional role in the system; iii) integrability, meaning the way to connect the other modules in the system; iv) scalability, given by the capacity of the system to process simultaneous several surfaces of the workpiece, by adding needed supplementary modules; v) diagnosability, defining the possibility of monitoring its functionality and to detect faults in the system.

ICTCM Research Center from Dunarea de Jos University is suggesting a new approach for this general concept, in order to obtain a good reaction of the industrial environment represented by investment to integrate the concept in the industry. This paper is presenting basic features of the concept of reconfigurable manufacturing systems, as was developed in ITCM Research Center.

In the second chapter it is presenting the new paradigms as they are defined by center's members. At the third, it is presenting key ideas to build the concepts. In the forth chapter, the conclusions are drawn, the further research needed for obtaining a better feedback from industry.

2. The new approach proposed

Major changes emerged on the market have determinated changes concerning material, data, knowledge, processing and orders as described bellow:

a) Material processing

At a concept level, nowadays, manufacturing systems can be divided in three main classes: universal, dedicated and flexible (Fig.1).

Universal manufacturing systems are based of universal machine tools and are design for irregular production. The economic efficiency level is low, but are still used at the present time, as it represent an investment that cannot be recovered. Dedicated systems are those rigid manufacturing systems, composed of machines with a high productivity but, with no adaptability to the requirements of the market. Presently, there are used for mass production, only of simple parts.

Flexible manufacturing system is defined by a basic numerically controlled machine tool and various modules to be added to complete its hardware architecture.

The system is reconfiguring according to the operation needed, using a certain module. The system provides low productivity associated with a high level of adaptability to the market. Compared to the dedicated system, where all modules are used continuously, in the case of flexible manufacturing system, most of the modules are not used. As a consequence, the investment in the modules is capital waste. This main aspect, as well as low productivity acts on flexible manufacturing system efficiency. In reconfigurable manufacturing system the aim is to combine high productivity of dedicated system with adaptability to the market of flexible system, in order to maximize economical efficiency small volume batch production.

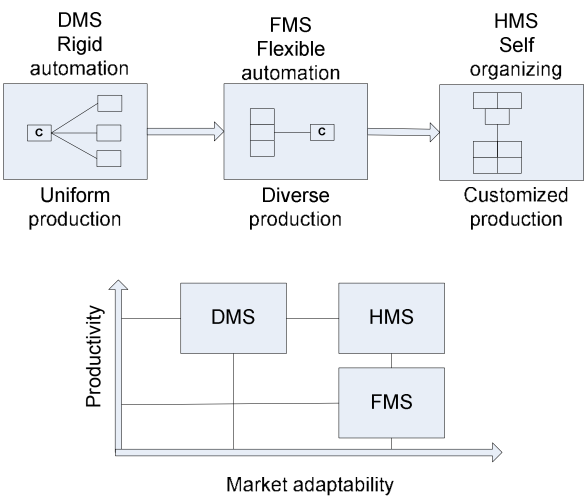

Figure 1. *Materials processing*

The modules used on this reconfigurable manufacturing system will be restrain and universal by combining the modules it can be achieved any configuration, the result is that all modules will be used continuously and consequently, and the capital waste will be nulled.

b) Data processing

In order to cover all the economic cycle, it is needed to process an important amount of data, beginning with price calculation, building offers for tender and continuing with design and manufacturing of the product. Along, the economic circuit, data are processed using CAD/CAM/CAB software. Present trend is to use software products to integrate as much as possible data flux. The last challenge, concerning data processing is using a CIB software (Computer Integrated Business).

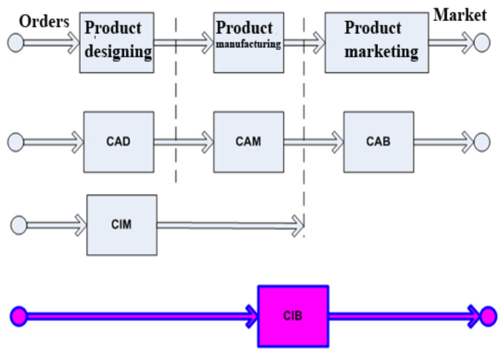

Fig.2. *Data processing*

c) Knowledge processing

In the past, the circuit of knowledge used in industrial activity started from data acquisition from experimental study, continued with research activity bringing new knowledge and by intermediary of scientifically papers, the knowledge was used to the manufacturing. The time needed to encompass this circuit it was considerable affecting efficiency level of using needed knowledge. Present trend wants to integrate manufacturing system control. That is, the data outputted from monitoring of the system are processed to obtain new knowledge, in order to use for an intelligent control.

This new approach brings two advantages: i) high speed of the processing loop compared with traditional architecture, ii) because data source is right on manufacturing system, where the knowledge will be used (not on experimental machine), and data are outputted from current machine state, during manufacturing (and not a simulation program of real functioning), the knowledge are accurate. On a larger scale, the process of knowledge capturing supports the development of the knowledge based industry.

d) Information processing

Currently, the part program is containing information concerning the machine tool operation, in order to process the product, taking into account quality requirements. As a consequence of this, the programmer begins with a requirements needed of product and continue assessing information’s from machining system model, getting the information needed for building the part program (important points coordinate, kinematical parameters). Present trend is to include the stage of part program generation into the machine tool facilities list, in order that part program to contain requirements needed for the product wanted, and not the way this should be processed to satisfied these requirements.

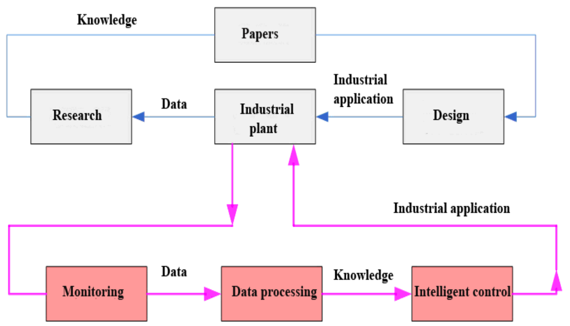

Fig.3. *Knowledge processing*

3. Reconfigurable manufacturing system- a new concept

This new vision was developed at ICTM Research Center from Dunărea de Jos University, Galați and is representing a first step towards new trend presented above. The concept was developed based on the following key ideas:

• reconfigurable manufacturing system hardware architecture is based on unitary structure of several modules, selected accordingly to the current processing needs.

• the level of reconfigurability act as an important factor for the economical side of the manufacturing system. In order to maximize the economical effect, reconfigurability should be used at the level of machine tool - devices –tool – part assembly. At the level of manufacturing system, the reconfigurability is adequate, but does not implie major effects. Furthermore, the reconfigurability concept used at the level of the machine tool is managing the level of reconfigurability for manufacturing system.

• Software architecture, different from the hardware architecture, must meet the requirements, to support a wide area of scenario, as a result of hardware reconfiguration of the system, based on the unitary approach for the machining process control, it can be developed as embedded system, in order to avoid the software reconfiguration actions, when hardware reconfiguration occurs.

• Monitoring should be based on different sensors embedded on system modules and to be extended at the level of all its components (machine, tool, part). Communication network between sensors, control unit and actuators should use a unitary protocol communication system. Therefore, total monitoring is replacing the actual surveillance activity as the nowadays manufacturing systems case. In addition to this, quality control, for instance dimensional accuracy must be integrated in the reconfigurable manufacturing system.

• Reconfigurable manufacturing system programming is simplified as the input is represented only by product parameters (including accepted deviations from the parameters), but not parameters needed for machine control

• Manufacturing system control must integrate technical, economical and commercial aspects and to allow virtual machining to predict the real system operation, in order to achieve predictive and optimal control for the machining process. Mathematical models describing system functioning should be obtain by online identification, as well for technical aspect and economical one. In this manner, specific knowledge fast extracted and applied, is replacing general knowledge, peculiarly processed, therefore the control is adapted.

4. Conclusions

1. Up to now, the reconfigurable manufacturing systems is not yet a matured area; this is why the industry feedback is not satisfactory.

2. Further research is necessary at the machine level, where the technical and economic consequences are very important, at entire manufacturing level.

3. The reconfigurable manufacturing systems development need a new conceptual approach based on the new paradigms, regarding data knowledge and information processing.

4. Virtual machining is an important candidate for productive control of the reconfigurable manufacturing system.

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Bibliography:

1. **Sung I. Kim, Robert G. Landers, A. Galip Ulsoy** (2003) – *Robust Machining Force Control with Process Compensation*, in Journal of Manufacturing Science and Engineering, DOI 10.1115/1.1580849.

2. **Y. S. Tarng, H. Y. Chuang, and W. T. Hsu** (2007) – *An Optimisation Approach of the Contour Error Control of CNC Machine Tools Using Genetic Algorithms*, in International Journal of Advanced Manufacturing Technologies, 13:359 - 366.

3. **Dr. Shankar Chakraborty, Arit Basu** (2006) – *Retrival of machining information from feature patterns using artificial neural networks*, in International Journal of Advanced Manufacturing Technologies, 27:781 – 787, DOI 10.1007/s00170-004-2254-9.

4. **Park, S. S.** (2006) – *Robust regenerative chatter stability in machine tools*, in International Journal of Advanced Manufacturing Technologies, DOI 10.1007/s00170-006-0778-x.

5. **Long, X.-H., Balachandran, B**. (2004) – *Stability analysis for milling process*, in Nonlinear Dynamics, DOI 10.1007/s11071-006-9127-8.

6. **Kyung Sam Park, Soung Hie Kim** (2002) – *Artificial intelligence approaches to determination of CNC machining parameters in manufacturing: a review*, in Atrificial Intelligence in Engineering 12: 127-134.

7. **Radu F. Babiceanu, F. Frank Chen** (2006) – *Development and applications of holonic manufacturing systems: a survey*, in Journal of Intelligent Manufacturing, 17, 111-131.

8. **Yoram Koren, Ann Arbor, A. Galip Ulsoy** (2002) – *Reconfigurable manufacturing system having a production capacity method for designing same and method for changing its production capacity*, in United States Patent, US 6, 349, 237 B1.

9. **Y. Liu, T. Cheng, L. Zuo** (2001) – *Adaptive Control Constraint of Machining Processes*, in International Journal of Advanced Manufacturing Technologies, 17:720-726.

10. **Steven Y. Liang, Rogelio L. Hecker**, Robert G. Landers (2004) – *Machining Processes Monitoring and Control: The State-of- the- Art*, in Journal of Manufacturing Science and Engineering, DOI 10.1115/1.1707035.

11. **R. Galan, J. Racero, I. Eguia, J.M. Garcia**, *A systematic approach for product families formation in Reconfigurable Manufacturing Systems*, Robotics and Computer-Integrated Manufacturing 23, 2007, 489–502

12. **Jaspreet Dhupia, Bartosz Powalka, Reuven Katz, A. Galip Ulsoy**, *Dynamics of the arch-type reconfigurable machine tool*, International Journal of Machine Tools & Manufacture 47, 2007, 326–334

13. **Steven Y. Liang, Rogelio L. Hecker, Robert G. Lander**s, *Machining Process Monitoring and Control*: The State-of-the-Art, Journal of Manufacturing Science and Engineering, May 2004, Volume 126, Issue 2, pp. 297-310

14. **Gou L, Luh P, Kyoya Y.** *Holonic manufacturing scheduling:architecture, cooperation mechanism and implementation*. Comput Ind 1998;37:213–31.

15. **Solberg J, Lin G.** *Integrated shop floor control using autonomous agents*. IIE Trans 1992;24(3):57–71.

16. **Markus A, Vancza T K, Monostori L.** *A market approach to holonic manufacturing*. Ann CIRP 1996;45:433–6.

17. **Sugimura N, Hiroi M, Moriwaki T, Hozumi K**. *A study on holonic scheduling for manufacturing system of composite parts*. Japan/USA Symposium on Flexible Manufacturing; 1996.

18. **Hino R, Moriwaki T.** *Decentralized scheduling in agent manufacturing system*. Proceedings of the second international Workshop on Intelligent Manufacturing Systems, Belgium, 1999, p. 41–7.

19. **Logie S, Sabaz D, Gruver WA**. *Sliding window distributed combinatorial scheduling using JADE.* Proceedings of the 2004 IEEE International Conference on Systems, Man and Cybernetics Netherlands, 2004, p. 1984–9.

20. **Rabelo R, Camarinha-Matos LM**. *Negotiation in multi-agent based dynamic scheduling.* Robot Comput Integ Manuf 1996;7(4): 257–70.

21. **Heikkila¨ T, Jarviluoma M, Juntunen T**. *Holonic control for manufacturing systems: design of a manufacturing robot cell.* Integ Comput Aided Eng 1997;4:202–18.

Sistemele de fabricaţie reconfigurabile – o noua generaţie

Rezumat

Centrul de cercetări ITCM din cadrul Universitarii Dunărea de Jos Galaţi propune o nouă abordare pentru acest concept general, pentru a obţine o reacţie pozitivă din partea industriei reprezentată de investiţii pentru a integra acest concept. Aceasta lucrare prezintă caracteristicile de bază a conceptului de maşină de fabricaţie reconfigurabilă aşa cum a fost dezvoltata în centrul de cercetări ITCM.

Rekonfigurierbar Fertigungssysteme - das folgende Erzeugung

Zusammenfassung

ICTCM Forschungszentrum von Dunarea de Jos University schlägt eine neue Annäherung für dieses allgemeine Konzept vor, um eine gute Reaktion von der Industrie zu erreichen, um das Konzept in der Industrie zu integrieren. Dieses Papier stellt grundlegende Eigenschaften des Konzeptes der reconfigurable Fertigungssysteme dar, wie im ITCM Forschungszentrum sich entwickelte.