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Components, Capabilities, Challenges, Characteristics of Reconfigurable Manufacturing System

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Abstract: ***This paper presents the review of Reconfigurable manufacturing system. That aims at achieving cost effective and rapid system changes needed, by incorporating principle of modularity, integrability and scalability as this new manufacturing system. Reconfigurable manufacturing system promises customized flexibility in a short time, while the other manufacturing system provides generalized flexibility designed for anticipation variations. Reconfigurable manufacturing system shows that it is desirable to change configuration when demand changes in order to minimize the unused capacity and functionality. This paper shows an overview of components of reconfigurable manufacturing system and comparisons of different manufacturing system with their merits and demerits are presented. The capabilities of reconfigurable manufacturing system, challenges of reconfigurable manufacturing system and key role in reconfigurable manufacturing system are explained. The characteristic of reconfigurable manufacturing system are also presented in this research paper.***

Keywords: Reconfigurablity, manufacturing systems, system, challenges, capabilities, characteristics

1. Introduction

A typical manufacturing company faces constantly changing product volumes and mix. It is commonly recognized that traditional manufacturing systems do not fit to present market competition and a shift is needed. The requirements of product design in the 21st century present an ever-increasing challenge. Consumers now demand products that suit their specific, yet constantly changing, needs. The changes of customer requirements create a need for new designs of manufacturing systems. In order to sustain competitiveness in dynamic markets, manufacturing organizations should provide the sufficient flexibility to produce a variety of products on the same system. In this way, advanced manufacturing systems need to accurately consider economical aspects as well as engineering aspects; otherwise, they cannot obtain a reasonable share of competitive market to justify their investments. RMSs are designed to rapidly produce different product families in the shortest time and at the lowest cost without sacrificing quality. The major characteristic of such systems is called reconfigurablity, which is the ability of rearranging and/or changing manufacturing elements aimed at adjusting to new environmental and technological changes.RMS may be defined as 'the manufacturing system designed at the outset for rapid changes in hardware and software components in order to quickly adjust production capacity within a part family in response to sudden changes in market or in regulatory requirements [14]. RMS as 'a manufacturing system in which a variety of products required by customers are classified into families, each of which is a set of similar products that corresponds to one configuration of the RMS [1]. An RMS is expected to be able to rapidly adjust to new circumstances by rearranging and changing its hardware and software components in order to accommodate not only the production of a variety of products but also the new product introduction within each family. Reconfigurable systems are designed to maintain a high level of performance by changing their configuration to meet multiple functional requirements or a change in operating conditions. A distinguishing feature of RMS is that its configuration evolves over time in order to provide the functionality and capacity needed, when it is needed. These configuration changes can be in the form of adding machines to the system. It is desirable to change configuration when demand changes in order to minimize the unused capacity and functionality. In summary, Reconfigurable Manufacturing System (RMS) is a manufacturing system with customized flexibility.

2. Comparisons of Different Manufacturing Systems

The reconfigurable manufacturing system will not be more expensive than flexible manufacturing system or even dedicated transfer lines. Reconfigurable Manufacturing Systems and Flexible Manufacturing Systems (FMS) have different goals. FMS aims at increasing the variety of parts produced. RMS aims at increasing the speed of responsiveness to markets and customers. RMS is also flexible, but only to a limited extent — its flexibility is confined to only that necessary to produce a part family. This is the customization characteristic, which is not the general flexibility that FMS offers. The advantages of customized flexibility are faster throughput and higher production rates [20]. Other important advantages of RMS are rapid scalability to the desired volume and convertibility, which are obtained within reasonable cost to manufacturers. The best application of a FMS is found in production of small sets of products. The dedicated transfer lines typically have high capacity but limited functionality. They are cost effective as long as they produce a single few parts types and demands exceeds supply but with saturated markets and increasing pressure of global competition, there are

situations where the dedicated transfer lines do not operate at their full capacity, which creates a loss. Flexible systems on the other hands are built with all the flexibilities and functionality available in some case, with those that may not be needed at installation time. The comparisons of different manufacturing systems are shown in table 1.

In terms of capacity and functionality, the reconfigurable manufacturing system always lies between the dedicated manufacturing system and flexible manufacturing system.

The RMS will be designed by the use of reconfigurable hardware and software, such that its capacity can be changed overtime and unlike the other manufacturing systems, it does not have a fixed hardware or software. It is clear that current trends in the reconfigurable software and reconfigurable hardware are the key enabling technologies of reconfigurable manufacturing system.

3. Components of Reconfigurable Manufacturing System

The reconfigurable manufacturing systems have two important components
1) Reconfigurable machine tool
2) Reconfigurable Controller

Reconfigurable Machine Tool
The uniqueness of reconfigurable manufacturing system is that the structure of the system as well as of its machines and control can be rapidly changed in response to market changes. A major component of RMS is the reconfigurable machine tools (RMT). By contrast, to conventional CNC those are general purpose machines, RMT are designed for specific customized range of operation requirement and may be cost effectively converted when the requirements change. Reconfigurable machine tools that are designed to produce specific set of features for specific range of cycle time. Some operation requirement will be constant over the life time of the machining system. The primary aim of the reconfigurable machine tool is to cope with various changes in the products or parts to be manufactured. The following possible changes must be taken in to consideration.

Work piece size
Part geometry and complexity
Production volume and production rates
Required processes
Accuracy requirement in terms of geometrical accuracy, surface quality
Material property such as kind of material, hardness etc.

The design of RMT requires broad knowledge of machine design, machine tool design, kinematics modeling and dynamics analysis. There is no comprehensive theory or design methodology that is directly applicable to the RMT design. The concept of reconfiguration has been used in related fields including fixture design, assembly system design and reconfigurable robots. Some typical motion types are defined as follows [4].

RMT Tool Machining Motion (TMM*):*
RMT (Tool machining motion) collects all reconfigurable machine tool motions, which are involved in the same machining feature (hole, slot, etc.). All of Tool point motions have the same directions (x-axis, y-axis, etc.) and perform the same machining task [13].

RMT Tool Machining Motion Family (TMMF*)*
An RMT TMMF is the collection of a series of machining motions among different work pieces, which can share the same motion types. According to reconfigurable machines, tools havefour important modules to develop reconfigurable machine tool control system as follows.
- Automatic Part Transfer System control module
- Automatic Part Clamping Rotating System control module
- Automatic Part Lifting System control module
- Automatic Tool Changing System control module.

Reconfigurable Controller
To control a particular machine, any machine specific functions or classes currently must be designed and built into a Reconfigurable Controller. The Reconfigurable controller becomes unchangeable at run-time for controlling different machines. The configuration system is directly interfaced so that it can receive configuration commands from this interface. Based on these different configuration instructions, the configuration system will do one of two operations. It will either set up a correct machine operational parameter, such as machine joint limits. After the configuration system finishes all of these configuration processes, the Reconfigurable controller is dynamically reconfigured for a particular mechanism. CAD/CAM applications can then pass the manufacturing process instructions to the Reconfigurable controller for direct machining.

4. Capabilities of Reconfigurable Manufacturing System

The reconfigurable capabilities could be divided into four different main dimensions [5].
- Product related change capabilities
- Change competency within operations
- Cooperation internally and externally
- People, knowledge, and creativity

Product Related Change Capabilities
Design for manufacturing is the most important area that plays a vital role to improve the product related capabilities if the products are designed for assembly this will make the system more productive. The products could also be designed for reconfigurablity in the sense of using similar material, redundancy, and efficient change over. The information technology is also the important area, which helps to improve the product related change capabilities. Information technologies have in some examples in industry been used to configure products providing customization in software instead of hardware. Software opens up for both flexibility and reconfigurablity if applied in this way.

Change Competencies within Operations
In the decision process the aspects of generating alternatives and evaluating are vital for successful decisions. Also, a condition for any decision process is the ability to generate and collect information. The gathering of information, generation of alternatives, and evaluation depends on which problem is being investigated [12]. Thus, creativity and innovations are central to formulating alternatives and solutions. Also a structured approach is vital in the decision-making process. This means that flexibility and reconfigurablity in conjunction to production system changes are very closely related to human beings within the production system and cannot be achieved by technology alone.

Cooperation Internally and Externally
Good product design and methods as design for assembly require good cooperation between design and manufacturing. So that several methodologies of concurrent engineering have been developed, this can be used to improve cooperation. As the production system spans over several actors it becomes more and more important to cooperate with other companies. Thus, the methodologies of concurrent engineering must also be expanded to include different companies.

People, Knowledge, and Creativity
The last defined dimension of reconfigurable capabilities is people, knowledge, and creativity. There exist numerous ways to develop these capabilities, mainly related to management issues. Motivation can be developed by good management and is in itself a large area for research.

5. Challenges of Reconfigurable Manufacturing System

The concept of reconfiguration has sparked interest in the academic and industrial communities. It has encouraged active research into supportive areas that are proving very beneficial to existing manufacturing systems, e.g., in the areas of process and production planning, fixturing, modular interfaces, and the like. Technology is available today to achieve a useful and affordable, physical and logical reconfiguration within manufacturing systems until new technologies are developed [6].
The several challenges of reconfigurable manufacturing system as follows:

1) Measures for changeability, flexibility, adaptability, responsiveness, reconfigurability and their relationships.
2) The hardware and software enabling technologies,
3) Reconfigurable logical support systems, such as logistics, production planning and control, process planning, tooling, and fixtures,
4) Balance of hard and soft capacity and functionality scalability options,
5) Design of machines, systems, and controls for flexibility, changeability, and reconfiguration and integration with current systems and software,
6) Models to determine adequate levels of changeability, flexibility, and reconfigurability required for different applications,
7) Appropriate capacity scalability policies
8) Appropriate frequency of change or reconfiguration,
9) Smooth and optimal systems transition and changeover,
10) Changeability and reconfiguration dependent quality factors, including human- related issues,
11) Complexity measurement, reduction, and management techniques,
12) The use of group technology to capitalize on commonality and standardization of parts, operation sequences, product structure, platforms, engineering.

6. Characteristics of Reconfigurable Manufacturing Systems

Various types of characteristics of Reconfigurable Manufacturing System are as follows:

Dynamic Behavior
The Dynamic behavior may be described from two senses, namely the reactive activities and the proactive activities. Adaptability of manufacturing systems mainly refers activities reactively adopted by a manufacturing system to adapt to environmental changes. High adaptability of a reconfigurable manufacturing system permits quick and cost-effective response to changes [7]. The reconfigurable manufacturing system will not only adapt to changes, it also has to be robust against some external changes, so they can keep a needed degree of stability for periods.

Integrated information
Manufacturing systems are able to select the necessary data from the data-overloaded environment and to filter the right information. This will be a major core competence of a system to guarantee its own survives in a fast changing and fast moving environment [8]. But beside the management of a huge amount of data, there is also the necessity for systems to ensure that the right persons get the needed information in a proper quality and also in time. Information integration meets requirements of communication and information sharing among autonomous units. Therefore, information integration is strongly related to intelligence and decision-making capabilities of reconfigurable organization units.

Oriented Innovation
Innovations will be one of the best characteristics supporting manufacturing reconfigurablity concerning products, processes, organizations and markets. There may be different kinds of innovations, such as technological or social innovations. Social innovations influence the behavior of the people within manufacturing systems and create an environment where people's imagination and creativity are encouraged. On the other hand, technology innovations are the activities that create new market demands.

Environment Consciousness
Reconfigurable manufacturing systems have to be environment-conscious. It takes the ecological concerns in the whole being of manufacturing systems and products into account. Reconfigurablity of manufacturing systems and products will reduce and avoid negative impacts on the environment to ensure a sustainable development [10].

Competition and Cooperation

Competition between manufacturing systems can be identified as another enabler to force the reconfigurablity of systems. It is one factor that leads to internal adaptation to be more competitive. Cooperation can be seen as a characteristic that causes internal changes but mainly influences the market and the behavior of the competitors. One can identify mainly vertical or horizontal cooperation between non-competing enterprises. But environmental constraints also force the cooperation between direct competitors.

7. Discussions & Conclusion

In this paper, we have introduced the concept of reconfigurable manufacturing systems (RMS), the Components of reconfigurable manufacturing system, capabilities of reconfigurable manufacturing system, challenges of reconfigurable manufacturing system, Characteristics of Reconfigurable Manufacturing Systems. The recent researches in reconfigurable design such as cost of reconfigurablity and variable selection for design has studied in this research paper. The challenges of reconfigurable manufacturing system have encouraged active role in supportive areas that are proving very beneficial to existing manufacturing systems. The reconfigurable manufacturing systems provide a viable solution for manufacturing situations where operations requirements change within prescribed bounds over the life times of the machine tool. However reconfigurable manufacturing systems are also designed such that they may be cost effectively converted when operations requirements change. Reconfigurable manufacturing systems are also capable of cost effectively to incorporating the new technologies. It is believed that reconfigurablity is of great importance for manufacturing systems to survive in the environments of high unpredictability. It has also been identified that new methodologies, technologies are to be developed to support reconfigurable manufacturing system.

Table 1: Weakness of Conventional Manufacturing System

Dedicated Manufacturing System	Flexible Manufacturing System
Not flexible For a single part Fixed capacity Not scalable Fixed verity	Expensive Machine focus Low throughput Single tool machines Complex

Table 2: Summary of Three Types of Manufacturing Systems

System	Definitions and objectives
Machining system	one or more metal removal machines tools and tooling that operate in coordinated manner to produce parts at required volume and quality
Dedicated manufacturing systems	A machining system designed for production of a specific part type at high volume. The objective of DMS is to cost effectively produce one specific part type at high volume and required quality
Flexible manufacturing system	Flexible Manufacturing System is an integrated system of manufacturing machine modules and material handling equipment under systems computer control for the automatic random processing of parts. The objective is to cost-effectively manufacture several types of parts, within pre-defined part families that can change over time, with minimum changeover cost.
Reconfigurable manufacturing system	A machining system which can be created by basic modules that can be arranged quickly and reliability.Reconfiguration will allow adding, removing or modifying specific process capabilities, control to adjust production capacity in response to market demands.Reconfigurable Manufacturing System is designed for rapid manufacturing change in structure in order to quickly adjust production capacity systems. The objective is to provide exactly the functionality and capacity that is needed, when it is needed.

Table 3: Comparison Of Different Manufacturing Systems

Sr. No.	Aspect	Traditional manufacturing system (DMS)	Conventional manufacturing system (FMS)	Advanced manufacturing system (RMS)
1	Process technology	Fixed	Needs to be adaptable	Responsive
2	Market	Stable	Predictable	Uncertain
3	Manufacturing policy	Pushing	Pulling	Customizing
4	The gap level between manufacturing system and demand variation	Very high	Medium	Low
5	Machine structure	Fixed	Fixed	Adjustable
6	System focus	Part	Machine	Part Family
7	Scalability	No	Yes	Yes
8	Flexibility	No	General	Customized
9	Operation of simultaneous tools	Yes	No	Yes
10	System Structure	Fixed	Adjustable	Adjustable
11	Cost	Low		intermediate

Appendix A: Table of Abbreviations.

Sr. No.	Description	Abbreviations
1	Numerically Controlled	NC
2	Computer Numerical Control	CNC
3	Distributed Numerical Control	DNC
4	Computer Aided Design	CAD
5	Computer Aided Manufacturing	CAM
6	Tool Point Motion	TPM
7	Tool-machining motion	TMM
8	Tool Machining Motion Family	TMMF
9	Flexible manufacturing system	FMS
10	Reconfigurable manufacturing system	RMS
11	Reconfigurable machine tool	RMT

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