Reconfigurable Manufacturing Systems

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INSPIRATION-WHIRLPOOL GALAXY

- 31 Million light years away.
- NGC 5194
- NGC 5195
• a. Introduction & Reconfigurable Products
• b. Reconfigurable Strategy
• c. Reconfigurable Issues & Design
• d. Reconfigurable Control
• e. TUT Activities
• f. The future...
Introduction - Discussion

What do you know of the history of manufacturing systems?

Think about –

Investment cost
Life cycle
Capacity scalability
Flexibility/Convertability
Introduction

- Flexible manufacturing systems (FMS) and dedicated manufacturing systems (DMS) have been the major manufacturing paradigms in the machine tool industry in the past.

Table 1

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Dedicated</th>
<th>Flexible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Cost</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Life Cycle</td>
<td>Low</td>
<td>Reasonable</td>
</tr>
<tr>
<td>Productivity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Capacity Scalability</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Flexible/Convertibility</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Summary of the characteristics of these manufacturing paradigms
Introduction (contd.)

Market place bombarded by constant change both locally and internationally.
Introduction (continued..)

- Product demand is unstable and rapidly changes
- Variety of products increase
- Rapidly changing customer needs
- Short window opportunities for new products
- World-wide competition

TURBULENT MARKET
Introduction (contd.)

Change characteristic in products requires adaptable hardware, software and people at all levels of an organisation.
Factory structure levels

1. Production network
2. Production locations
3. Production segments
4. Production systems
5. Production cells
6. Workplaces Machines
7. Process chains

reconfiguration of production structure
reconfiguration of factory layouts and system configuration
reconfiguration of facilities and processes
Factory structure levels

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   Machines
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Reconfiguration of production structure
Reconfiguration of factory layouts and system configuration
Reconfiguration of facilities and processes
Introduction (contd.)

The RMS emanates from the dynamic nature of the manufacturing environment and the global competition that now exists among nations.
Reconfigurable Products

Toy House

Cell phone-TV-Camera-laptop

Gripper for Packing

Rock, Roll & Ride
Requirements of RMS environment

- Short lead time-bit competition, maximum profits, retain large market share
- More variants-versatile and customerized
- Fluctuating & Low volumes-limited market niches, shorter life cycles, fragmentation of market due to customisation
- Low prices-globalized market offers customers with more windows to purchase low-price products
A manufacturing system is functioned to meet customer requirements (CR) by producing required products (RP).

- The final product is an assembly of a set of basic parts.

- **Design**-defines system components and assemblies thereof based on CR.
- **Manufacturing**-fabrication of the basic parts.
- **Assembly**-put all the basic parts together to create final products for customers.
STRATEGY TO REDUCE TIME

- Lead time is referred to as time required to meet customer requirements.
  1. Reduce or eliminate indirect activities such as transferring and buffering.
  2. Increase the system capacity and reduce system ramp-up time.
  3. Operate the system concurrently.
STRATEGY TO INCREASE VARIANTS

• Variation of a product can be by using varying different types of parts and/or different assemblies.

1. Balance manufacturing and assembly activities and resources for efficient use.

2. Manufacturing resource variants can be increased or made more versatile. Ability to produce varying parts is enhanced.

3. More variants of assembles can be increased by increasing the variants and versatility of the assembly resources.
Active Learning

Think of a product with a lot of variety that is in the market, how can the strategy to increase variants be applied to this product?
• VARIANT INCREASE
STRAEGY FOR LOW & FLACTUATING VOLUMES

• Product platform is a set of subsystems and interfaces that form a common structure for efficiently developing a stream of related products.

• A good product platform may reduce system sensitivity to change on product volume;

• Change of the product volume has a great impact on the required manufacturing capability.

1. Modularise the product platform.

2. Reconfigure resources (manufacturing & assembly) dynamically to adapt to new products.
STRATEGY FOR LOW & FLACTUATED VOLUME
STRATEGY TO REDUCE COST

• Organisation of activities and resources has an impact on cost

1. Reduce or eliminate cost caused by indirect activities.
2. Reduce cost caused by direct activities.
3. Reduce the cost by system integration.
4. The increase of the market returns can alleviate the cost burden.
Reconfigurable Manufacturing Systems

A RMS is a system designed at the outset for rapid changes in structure, as well as in its hardware and software components, in order to quickly adjust production capacity and functionality (within a part family) in response to market changes. (Koren)

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<table>
<thead>
<tr>
<th>Fixed Hardware</th>
<th>Reconfigurable Hardware</th>
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<tbody>
<tr>
<td>No Software</td>
<td>Manual Machines</td>
</tr>
<tr>
<td></td>
<td>Dedicated Lines</td>
</tr>
<tr>
<td>Fixed Software</td>
<td>CNC, Robots</td>
</tr>
<tr>
<td></td>
<td>F M S</td>
</tr>
<tr>
<td>Reconfigurable Software</td>
<td>Modular Machines</td>
</tr>
<tr>
<td></td>
<td>Reconfigurable Machines w. Reconfigurable Controllers</td>
</tr>
</tbody>
</table>

OTHER RMS DEFINITIONS

• Liles and Huff-A system capable of tailoring the configuration of a manufacturing system to meet the production demands placed on it dynamically.

• Other similar concepts to the RMS paradigm are:

• Modular manufacturing

• Component-based manufacturing system

• Modular product system

• Modular flexible manufacturing

• The primary goal of all these is to meet the changes and uncertainties of the manufacturing environment.

• Considering the fact that reconfiguration varies from the low levels of system organisation to the high levels an extension of Korens definition “An RMS has an ability to reconfigure hardware and control resources at all of the functional and organisational levels, in order to quickly adjust production capacity and functionality in response to sudden changes in market or in regulatory requirements.”
RMS DESIGN ISSUES

ARCHITECTURAL DESIGN-involved at phase of system design
Determines system components and their interactions. The components are encapsulated in modules.
Interactions are the options when the modules are assembled.
Has to be designed to produce as many system variants as possible, so system can deal with changes and uncertainties cost effectively.

CONFIGURATION DESIGN-involved at the phase of system application
Determines system configuration under a given system architecture for a specific task.
A configuration is an assembly of the selected modules; it can fulfill the given tasks optimally.

CONTROL DESIGN-involved at phase of system operation
Determines appropriate process variables (joint displacement, velocities, joint module)
Configuration is operated to fulfill the task satisfactorily
ARCHITECTURE DESIGN CHARACTERISTICS

• **Modularity** - both hardware and software elements are modular.

• **Scalability** - the system is scalable in terms of volume.

• **Integrability** - system and the system components are designed for ready system integration and future introduction of new technology.

• **Convertibility** - allows quick changeover between existing products and quick system adaptability for future products.

• **Diagnosability** - ability to quickly identify the sources of quality and reliability problems that occur in large systems.
APPLICATIONS OF AN RMS SCENARIO

Reconfigurable Fixturing System
Reconfigurable Assembly System
Reconfigurable Machining System
Reconfigurable Material-Handling System
Reconfigurable Software System

Raw Materials → Product
RMS HARDWARE SYSTEMS

• **Reconfigurable machining systems**—modular machines have been defined since the 70s. Projects have been implemented to customised the configuration of modular tools. Parallel Kinematic Machines (PKM) also fall into this category of the RMS.

• **Reconfigurable fixturing systems**—It is composed of basic modules including locators, clampers and connectors, specialised materials or adjustable components are utilised in the changeable fixtures.

• **Reconfigurable assembly systems**—these are usually robotised. This can be improved if the robot system itself has been modularised. Use of robots to calibrate reconfigurable assembly systems automatically will reduce ramp-up time.

• **Reconfigurable Handling systems**—the main components are autonomous robots. Reconfigurable conveyor systems have also been developed allowing real-time volume change of the product. Programmable conveyors have also been developed.

• **Higher reconfigurable systems**—These are the system level aspects of the RMS in a shop floor like for instance five machine cells, each cell including two or three workstations devoted to particular tasks.
The system architecture determines the available types and assembly options of system components. It thus determines what configuration variations a system can produce.
CONTROL DESIGN IN RMS

- There are two main variables to be manipulated:
- Reconfigurable variables—change the mechanism, e.g., MT or ROBOT configuration
- Process variables—change the end effector motion
CONTROL DESIGN IN RMS

• DESIGN REQUIREMENTS
• Control system should be autonomous
• Control system should be distributed and modularised
• Control system should be open
• Control system should be scalable and upgradeable
• Control system should be self reconfigured
• Control system should be able to identify changes of task specifications.
RECONFIGURABLE SYSTEM CONTROL REQUIREMENTS
TUT-RVS

Reconfigurable Vibrating Screen (RVS)
TUT-RBPM

Reconfigurable Bending Press Machine
Short Summary

- Manufacturing Enterprise
  - Product
  - Process
  - Business

- Innovative Products
- Personalized Production to customer's taste
- Culturally Suitable
- Agile Supply Chains
- Leadership & Alliances
- Assembly Facilities Close to Customers
- Market Demand
- Cost
- Quality
- Responsiveness
- Customer Needs
- Production Disruptions

- Exactly what needed
- Shortest time

- The rising future
- Exactly what needed
- Shortest delivery time

- The rising future with RMS!
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