Flexible Manufacturing System (Strategy) (FMS)

Conceptual idea is attributed to David Williamson in the 1960’s, but it took development of CNC and programmable controllers to make the concept truly viable.

Topics

- Current world & business environment
- Manufacturing system basics
- Types of flexibility
- Flexible manufacturing system (FMS)
- Flexible manufacturing cell (FMC)
- System trade-offs

What's Happening Today?

- Capital costs are increasing
- Change
- Multi-national marketplace
- Change
- Value of $ is changing
- Change
- Incredible market dynamics
- Change
- “Virtual” technology explosion
- Change
Definition: Manufacturing System

A manufacturing system is a collection of integrated equipment and human resources, whose function is to perform one or more processing and/orassembly operations on a starting raw material, part, or set of parts.

Manufacturing System Components

- What are they?
- How are they combined?
- How are they organized?
- Production machines
- Material handling system
- Computer control system
- Human resources
## Classification of Manufacturing Systems

- Types of operations
- Number of workstations & layout
- Level of automation
- Part or product variety (how to handle; types of flexibility)

## Types of Manufacturing Systems

- Mass production (transfer line)
- Special systems
- Flexible manufacturing system (FMS)
- Flexible manufacturing cell (FMC)
- Stand-alone CNC systems

## Why FMS??

- Increased Productivity
- Cost-effective Investment
- Flexibility
  - High Quality
  - Lower Cost
  - Shorter Lead Time
  - Respond to Change
FMS is Business Driven

- Improved profitability
  - Reduced lead times
  - Reduced inventory levels
  - Rapid response to market changes
  - Lower staffing levels
- Improved manufacturing effectiveness
  - Increased operational flexibility
  - Increased predictability
  - Increased control

FMS: Impact on Manufacturing

- Need for managing change
- More complex products
- Need for greater flexibility
- Need for faster time-to-market

Definition: FMS

Group of machines or processes, integrated with material handling equipment, and under the direction of a (central) control system, to produce a variety of parts, at non-uniform production rates, batch sizes & quantities.
Part Design Flexibility vs. Operating Flexibility

Types of FMS Flexibility*

- Product design — Makes it possible to accommodate a variety of product designs, including new products and modified designs; stems from recent advances in manufacturing controls that allow design details to reside in machine software rather than the mechanics of its physical structure.


Types of FMS Flexibility (cont’d)

- Operating — Makes it possible to reduce manufacturing costs while responding to changes in manufacturing conditions, such as production schedules and model mix; characterized by capability to make up lost production (achieved in past through large WIP inventory).

- System — Makes it possible to add or change existing manufacturing processes to increase productivity. Rembold et al. 1993
FMS: Important Technologies

- Microprocessor
- Digital system simulation
- Design optimization tools
- Computer aided process planning
- Process controlled quality
- More software control
- Advanced industrial controls
- Industrial robots

FMS: Other Significant Technologies

- Advanced sensors
- Improved diagnosis
- Higher speed
- On-line/in-process inspection
- Quick-change tooling
- Tool wear monitor
- Development with other processes, e.g., forming; heat treat; assembly

Invest or Not Invest??

- Type of equipment available vs. operations needed
- Types of parts & number of part #s
- Part tolerances & material requirements
- Design change expected
- Operational/schedule change expected
## Invest or Not Invest?? (cont'd)

- Production volumes
- Product life & lead time requirements
- Direct labor available
- Dollars available to invest
- Other investment alternatives for company

## Part Manufacturing Target for FMS

- Mid-volume
- Mid-variety

## Production Volume vs. Product Flexibility

<table>
<thead>
<tr>
<th>Production Volume (parts/yr)</th>
<th>Product Flexibility (no. of part nos.)</th>
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System Trade-offs

- Transfer lines
  - Large volume production/high output rate (~15,000+ parts/yr)
  - Parts are virtually identical; sometimes only one part
  - Changeover difficult/requires shutdown of line & machine retooling
  - Need to replace machines for major design changes

Transfer Line

System Trade-offs (cont’d)

- Stand-alone CNC
  - Efficiently accommodates part design change
  - Reprogram for design changeover/design change
  - Low production quantities (~up to 800 parts/yr)
- CIMS
  - Between high production rates & high flexibility (mid-volume)
  - Fills in gap between transfer lines & low volume CNC machines
System Trade-offs (cont'd)

- **Special system**
  - Least flexible CIMS
  - Limited number of different parts (e.g., 2-8) in same family (volume: ~1500-15,000)
  - Includes special purpose machine tools
  - Lot sizes: 200-10,000
  - Similar to transfer line in flow

- **Flexible manufacturing cell (FMC)**
  - Most flexible of CIMS, but lowest production rate (40-800 different parts @ 15-500/yr)
  - Mixed CNC machine tools, maybe w/o automated m.h.

- **FMS**
  - Several part families, e.g., 4-100 different part #s with 40-2000/yr
  - Lot sizes may vary between less than 50 to 500 or more
  - Central load/unload & palletized fixtures
  - Routing varies with part loading & FMS type
  - Typically central computer (monitor, schedule & control)
FMS Concepts

- Single station routing part flow
- Sequential routing part flow
- Random routing part flow

FMS Concepts

- Single station
  - Tailor to design or operational change need
  - Attributes of both random & sequential flow
  - Problem areas: overall accuracy & required head investment

Single Station FMS
FMS Concepts (cont'd)

- Sequential flow
  - Accommodates operational part mix change; higher throughput capacity
  - Similar operation sequences
  - Simpler material handling
  - Potential problems: over & under utilization; machines repeated for repeated operations
Sequential FMS Examples

Random FMS

FMS Concepts (cont'd)

- Random flow
  - High degree of design flexibility & limited operating flexibility
  - Complex material handling system
  - Potential problems: availability of machine tools; reduced capacity with over & under utilized machine tools
### FMS: Machine Tool Trade-offs

<table>
<thead>
<tr>
<th>Machine Tool</th>
<th>Tooling</th>
<th>Flexibility</th>
<th>Prod. Rate</th>
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</thead>
<tbody>
<tr>
<td>Head Changer</td>
<td>multiple tool</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Head Indexer</td>
<td>multiple tool</td>
<td>lowest</td>
<td>highest</td>
</tr>
<tr>
<td>Machining Center</td>
<td>single point (spindle)</td>
<td>highest</td>
<td>lowest</td>
</tr>
</tbody>
</table>

### Computer Functions for FMS
- Control of each workstation
- Distribution of control instructions to workstations
- Production control
- Traffic control
- Shuttle control
- Workhandling system monitoring
- Tool control
- System performance monitoring & reporting

### Personnel Requirements for FMS
- System manager
- Electrical technician
- Mechanical/hydraulic technician
- Tool setter
- Fixture setup & lead man
- Load/unload man
- Rover operator
- Other: NC programmer; computer programmers; other support staff
Benefits to Business Elements

- Manufacturing
  - Combine low part volumes to get economies of scale
  - Single system manager benefits
  - Adaptable to several product life cycles
  - Simplified new product introduction on existing equipment
- Product Engineering (Design)
  - Facilitates design update & refinement
  - Encourages design innovation
  - Facilitates use of existing designs for new applications

Benefits to Business Elements (cont’d)

- Marketing
  - Lower cost basis for mid-volume production
  - Shorter lead times/adapt to market dynamics
  - Expand capacity to growth needs
  - Respond to schedule/model mix
- Finance
  - Better use of capital investment dollars
  - Better tailor capacity & volume
  - Produce old & new designs on the same production equipment
  - Lower new product introduction cost

Manufacturing Cells

- Single station manned cells
- Single station automated cells
- Applications of single station cells
- Analysis of single station cells
**Single Station Manned Cells**

- Requires shortest amount of time to implement
- Requires least capital investment
- Technologically, easiest to install & operate
- Often results in lowest cost per unit produced
- Most flexible manufacturing system

**Single Station Automated Cells**

- Reduced labor requirement/cost
- Easiest & least expensive among automated systems to implement
- Higher production rates possible
- First step in implementing integrated multi-station automated system

**Applications of Single Station Cells**

- CNC machining center with parts carousel & automatic pallet changer
- CNC turning center with parts storage tray & robot (same or different parts)
- Cluster of CNC turning centers, each producing different part
- Plastic injection molding machine with mechanical arm to remove part
- Automated electronic assembly machine
- Robotic assembly cell
- Stamping press that punches & forms small sheet metal parts
Analysis of Single Station Cells

- Determine number of required workstations
  - Include setup time
  - Consider availability & machine utilization
  - Consider worker efficiency
  - Consider defect rate
- Determine number of machines for single worker (cluster of machines)

System Trade-offs

- Advantages vs. disadvantages
- Pluses vs. minuses
- Pluses vs. other pluses
- Cost vs. benefits
- Optimization strategies