THE FUTURE OF INDUSTRIAL AUTOMATION

FLEXIBLE MANUFACTURING SYSTEMS (FMS)

Report to

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Introduction

In the middle of the 1960s, market competition became more intense.

During 1960 to 1970 cost was the primary concern. Later quality became a priority. As the market became more and more complex, speed of delivery became something customer also needed.

A new strategy was formulated: Customizability. The companies have to adapt to the environment in which they operate, to be more flexible in their operations and to satisfy different market segments (customizability).

Thus the innovation of FMS became related to the effort of gaining competitive advantage.

First of all, FMS is a manufacturing technology.

Secondly, FMS is a philosophy. "System" is the key word. Philosophically, FMS incorporates a system view of manufacturing. The buzz word for today’s manufacturer is "agility". An agile manufacturer is one who is the fastest to the market, operates with the lowest total cost and has the greatest ability to "delight" its customers. FMS is simply one way that manufacturers are able to achieve this agility.

An MIT study on competitiveness pointed out that American companies spent twice as much on product innovation as they did on process innovation. Germans and Japanese did just the opposite.

In studying FMS, we need to keep in mind what Peter Drucker said: "We must become managers of technology not merely users of technology".

Since FMS is a technology, well adjusted to the environmental needs, we have to manage it successfully.

1. Flexibility concept. Different approaches

Today flexibility means to produce reasonably priced customized products of high quality that can be quickly delivered to customers.

Different approaches to flexibility and their meanings are shown Table 1.
Table 1

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<th>Approach</th>
<th>Flexibility meaning</th>
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| **Manufacturing** | - The capability of producing different parts without major retooling  
               - A measure of how fast the company converts its process(es) from making an old line of products to produce a new product  
               - The ability to change a production schedule, to modify a part, or to handle multiple parts |
| **Operational** | - The ability to efficiently produce highly customized and unique products |
| **Customer** | - The ability to exploit various dimension of speed of delivery |
| **Strategic** | - The ability of a company to offer a wide variety of products to its customers |
| **Capacity** | - The ability to rapidly increase or decrease production levels or to shift capacity quickly from one product or service to another |

So, what is flexibility in manufacturing?

While variations abound in what specifically constitutes flexibility, there is a general consensus about the core elements. There are three levels of manufacturing flexibility.

(a) Basic flexibilities

- *Machine flexibility* - the ease with which a machine can process various operations  
- *Material handling flexibility* - a measure of the ease with which different part types can be transported and properly positioned at the various machine tools in a system  
- *Operation flexibility* - a measure of the ease with which alternative operation sequences can be used for processing a part type
(b) System flexibilities

- **Volume flexibility** - a measure of a system’s capability to be operated profitably at different volumes of the existing part types
- **Expansion flexibility** - the ability to build a system and expand it incrementally
- **Routing flexibility** - a measure of the alternative paths that a part can effectively follow through a system for a given process plan
- **Process flexibility** - a measure of the volume of the set of part types that a system can produce without incurring any setup
- **Product flexibility** - the volume of the set of part types that can be manufactured in a system with minor setup

(c) Aggregate flexibilities

- **Program flexibility** - the ability of a system to run for reasonably long periods without external intervention
- **Production flexibility** - the volume of the set of part types that a system can produce without major investment in capital equipment
- **Market flexibility** - the ability of a system to efficiently adapt to changing market conditions

2. Seeking benefits on flexibility

Today’s manufacturing strategy is to seek benefits from flexibility. This is only feasible when a production system is under complete control of FMS technology. Having in mind the Process-Product Matrix you may realize that for an industry it is possible to reach for high flexibility by making innovative technical and organizational efforts. See the Volvo’s process structure that makes cars on movable pallets, rather than an assembly line. The process gains in flexibility. Also, the Volvo system has more flexibility because it uses multi-skill operators who are not paced by a mechanical line.

So we may search for benefits from flexibility on moving to the job shop structures.

Actually, the need is for **flexible processes** to permit rapid low cost switching from one product line to another. This is possible with **flexible workers** whose multiple skills would develop the ability to switch easily from one kind of task to another.

As main resources, flexible processes and flexible workers would create **flexible plants** as plants which can adapt to changes in real time, using movable equipment, knockdown walls and easily accessible and re-routable utilities.
3. FMS- an example of technology and an alternative layout

The idea of an FMS was proposed in England (1960s) under the name "System 24", a flexible machining system that could operate without human operators 24 hours a day under computer control. From the beginning the emphasis was on automation rather than the "reorganization of workflow".

Early FMSs were large and very complex, consisting of dozens of Computer Numerical Controlled machines (CNC) and sophisticated material handling systems. They were very automated, very expensive and controlled by incredibly complex software. There were only a limited number of industries that could afford investing in a traditional FMS as described above.

Currently, the trend in FMS is toward small versions of the traditional FMS, called flexible manufacturing cells (FMC).

Today two or more CNC machines are considered a flexible cell and two or more cells are considered a flexible manufacturing system.

Thus, a Flexible Manufacturing System (FMS) consists of several machine tools along with part and tool handling devices such as robots, arranged so that it can handle any family of parts for which it has been designed and developed.

Different FMS levels are:

Flexible Manufacturing Module (FMM). Example: a NC machine, a pallet changer and a part buffer;

Flexible Manufacturing (Assembly) Cell (F(M/A)C). Example: Four FMMs and an AGV (automated guided vehicle);

Flexible Manufacturing Group (FMG). Example: Two FMCs, a FMM and two AGVs which will transport parts from a Part Loading area, through machines, to a Part Unloading Area;

Flexible Production Systems (FPS). Example: A FMG and a FAC, two AGVs, an Automated Tool Storage, and an Automated Part/assembly Storage;

Flexible Manufacturing Line (FML). Example: multiple stations in a line layout and AGVs.

4. Advantages and disadvantages of FMSs implementation

Advantages

- Faster, lower- cost changes from one part to another which will improve capital utilization
- Lower direct labor cost, due to the reduction in number of workers
- Reduced inventory, due to the planning and programming precision
- Consistent and better quality, due to the automated control

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• Lower cost/unit of output, due to the greater productivity using the same number of workers
• Savings from the indirect labor, from reduced errors, rework, repairs and rejects

**Disadvantages**

• Limited ability to adapt to changes in product or product mix (ex. machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS)
• Substantial pre-planning activity
• Expensive, costing millions of dollars
• Technological problems of exact component positioning and precise timing necessary to process a component
• Sophisticated manufacturing systems

FMSs complexity and cost are reasons for their slow acceptance by industry. In most of the cases FMCs are favored.

### 5. The Future of FMS

- FMS systems which deliver directly into warehouse, and do not require labor
- The use of robots that have vision, and tactile sensing to replace human labor
- Technology will make 100% inspection feasible. Thus making faster process adjustment possible.
- Computer diagnosis will improve estimation of machine failure, and guide work crews repairing failures.
- International coordination and control of manufacturing facilities.
- Customers have completely custom orders made immediately, and to exact specifications, and at a lower cost
- Networks will tend to eliminate the barriers caused by international borders
- Standards will be developed which make installation of a new machine trivial
- Networking between manufacturers and suppliers will streamline the inventory problems
- Marketing will be reduced, as customer desires are met individually, and therefore do not need to be anticipated by research.
- Finished goods inventories will fall as individual consumer needs are met directly.
- Better management software, hardware, and fixturing techniques will push machine utilization towards 100%
- The task of Design and Process Planning will become highly automated, therefore reducing wasted time on repetitious design, and discovering careless mistakes.
- Simplification of systems overall - MRP, MPCS, etc.
- More front end simulation
- Computing power increases - more sophisticated tools

### 6. Robotics Technology Trends

When it comes to robots, reality still lags science fiction. But, just because robots have not lived up to their promise in past decades does not mean that they will not arrive sooner or later. Indeed, the confluence of several advanced technologies is bringing the age of robotics ever nearer – smaller, cheaper, more practical and cost-effective.
Brawn, Bone & Brain

There are 3 aspects of any robot:

- **Brawn** – strength relating to physical payload that a robot can move.
- **Bone** – the physical structure of a robot relative to the work it does; this determines the size and weight of the robot in relation to its physical payload.
- **Brain** – robotic intelligence; what it can think and do independently; how much manual interaction is required.

Because of the way robots have been pictured in science fiction, many people expect robots to be human-like in appearance. But in fact what a robot looks like is more related to the tasks or functions it performs. A lot of machines that look nothing like humans can clearly be classified as robots. And similarly, some human-looking robots are not much beyond mechanical mechanisms, or toys.

Many early robots were big machines, with significant brawn and little else. Old hydraulically powered robots were relegated to tasks in the 3-D category – dull, dirty and dangerous. The technological advances since the first industry implementation have completely revised the capability, performance and strategic benefits of robots. For example, by the 1980s robots transitioned from being hydraulically powered to become electrically driven units. Accuracy and performance improved.

**Industrial robots already at work**

The number of robots in the world today is approaching 1,000,000, with almost half that number in Japan and just 15% in the US. A couple of decades ago, 90% of robots were used in car manufacturing, typically on assembly lines doing a variety of repetitive tasks. Today only 50% are in automobile plants, with the other half spread out among other factories, laboratories, warehouses, energy plants, hospitals, and many other industries.

Robots are used for assembling products, handling dangerous materials, spray-painting, cutting and polishing, inspection of products. The number of robots used in tasks as diverse as cleaning sewers, detecting bombs and performing intricate surgery is increasing steadily, and will continue to grow in coming years.

**Robot intelligence**

Even with primitive intelligence, robots have demonstrated ability to generate good gains in factory productivity, efficiency and quality. Beyond that, some of the "smartest" robots are not in manufacturing; they are used as space explorers, remotely operated surgeons and even pets – like Sony's AIBO mechanical dog. In some ways, some of these other applications show what might be possible on production floors if manufacturers realize that industrial robots don't have to be bolted to the floor, or constrained by the limitations of yesterday's machinery concepts.

With the rapidly increasing power of the microprocessor and artificial intelligence techniques, robots have dramatically increased their potential as flexible automation tools. The new surge of robotics is in applications demanding advanced intelligence. Robotic technology is

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converging with a wide variety of complementary technologies – machine vision, force sensing (touch), speech recognition and advanced mechanics. This results in exciting new levels of functionality for jobs that were never before considered practical for robots.

The introduction of robots with integrated vision and touch dramatically changes the speed and efficiency of new production and delivery systems. Robots have become so accurate that they can be applied where manual operations are no longer a viable option. Semiconductor manufacturing is one example, where a consistent high level of throughput and quality cannot be achieved with humans and simple mechanization. In addition, significant gains are achieved through enabling rapid product changeover and evolution that can't be matched with conventional hard tooling.

Boosting Competitiveness

As mentioned, robotic applications originated in the automotive industry. General Motors, with some 40-50,000 robots, continues to utilize and develop new approaches. The ability to bring more intelligence to robots is now providing significant new strategic options. Automobile prices have actually declined over the last two to three years, so the only way that manufacturers can continue to generate profits is to cut structural and production costs.

When plants are converted to new automobile models, hundreds of millions of dollars are typically put into the facility. The focus of robotic manufacturing technology is to minimize the capital investment by increasing flexibility. New robot applications are being found for operations that are already automated with dedicated equipment. Robot flexibility allows those same automated operations to be performed more consistently, with inexpensive equipment and with significant cost advantages.

Robotic Assistance

A key robotics growth arena is Intelligent Assist Devices (IAD) – operators manipulate a robot as though it were a bionic extension of their own limbs with increased reach and strength. This is robotics technology – not replacements for humans or robots, but rather a new class of ergonomic assist products that helps human partners in a wide variety of ways, including power assist, motion guidance, line tracking and process automation.

IAD’s use robotics technology to help production people to handle parts and payloads – more, heavier, better, faster, with less strain. Using a human-machine interface, the operator and IAD work in tandem to optimize lifting, guiding and positioning movements. Sensors, computer power and control algorithms translate the operator's hand movements into super human lifting power.

New robot configurations

As the technology and economic implications of Moore's law continue to shift computing power and price, we should expect more innovations, more cost-effective robot configurations, more applications beyond the traditional “dumb-waiter” service emphasis.

The biggest change in industrial robots is that they will evolve into a broader variety of structures and mechanisms. In many cases, configurations that evolve into new automation systems won't be immediately recognizable as robots. For example, robots that automate semiconductor manufacturing already look quite different from those used in automotive plants.
We will see the day when there are more of these programmable tooling kinds of robots than all of the traditional robots that exist in the world today. There is an enormous sea change coming; the potential is significant because soon robots will offer not only improved cost-effectiveness, but also advantages and operations that have never been possible before.

**Envisioning Vision**

Despite the wishes of robot researchers to emulate human appearance and intelligence, that simply hasn't happened. Most robots still can't see – versatile and rapid object recognition is still not quite attainable. And there are very few examples of bipedal, upright walking robots such as Honda’s P3, mostly used for research or sample demonstrations.

A relatively small number of industrial robots are integrated with machine vision systems – which is why it's called machine vision rather than robot vision. The early machine vision adopters paid very high prices, because of the technical expertise needed to “tweak” such systems. For example, in the mid-1980s, a flexible manufacturing system from Cincinnati Milacron included a $900,000 vision guidance system. By 1998 average prices had fallen to $40,000, and prices continued to decline.

Today, simple pattern matching vision sensors can be purchased for under $2,000 from Cognex, Omron and others. The price reductions reflect today's reduced computing costs, and the focused development of vision systems for specific jobs such as inspection.

**Robots already in use everywhere**

Sales of industrial robots have risen to record levels and they have huge, untapped potential for domestic chores like mowing the lawn and vacuuming the carpet. Last year 3,000 underwater robots, 2,300 demolition robots and 1,600 surgical robots were in operation. A big increase is predicted for domestic robots for vacuum cleaning and lawn mowing, increasing from 12,500 in 2000 to almost 500,000 by the end of 2004. IBot’s Roomba floor cleaning robot is now available at under $200.00.

In the wake of recent anthrax scares, robots are increasingly used in postal sorting applications. Indeed, there is huge potential to mechanize the US postal service. Some 1,000 robots were installed last year to sort parcels and the US postal service has estimated that it has the potential to use up to 80,000 robots for sorting.

Look around at the “robots” around us today: automated gas pumps, bank ATMs, self-service checkout lanes – machines that are already replacing many service jobs.

Fast-forward another few decades. It doesn't require a great leap of faith to envision how advances in image processing, microprocessor speed and human-simulation could lead to the automation of most boring, low-intelligence, low-paying jobs.

Marshall Brain (yes, that's his name) founder of HowStuffWorks.com has written a couple of interesting essays about robotics in the future, well worth reading. He feels that it is quite plausible that over the next 40 years robots will displace most human jobs. According to Brain's projections, in his essay "Robotic Nation", humanoid robots will be widely available by 2030. They will replace jobs currently filled by people for work such as fast-food service, housecleaning and retail sales. Unless ways are found to compensate for these lost jobs, Brain estimates that more than 50% of Americans could be unemployed by 2055 – replaced by robots.

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7. The Future of Industrial Automation

The rear-view mirror

Because of the relatively small production volumes and huge varieties of applications, industrial automation typically utilizes new technologies developed in other markets. Automation companies tend to customize products for specific applications and requirements. So the innovation comes from targeted applications, rather than any hot, new technology.

Over the past few decades, some innovations have indeed given industrial automation new surges of growth: The programmable logic controller (PLC) – developed by Dick Morley and others – was designed to replace relay-logic; it generated growth in applications where custom logic was difficult to implement and change. The PLC was a lot more reliable than relay-contacts, and much easier to program and reprogram. Growth was rapid in automobile test-installations, which had to be re-programmed often for new car models. The PLC has had a long and productive life – some three decades – and (understandably) has now become a commodity.

At about the same time that the PLC was developed, another surge of innovation came through the use of computers for control systems. Mini-computers replaced large central mainframes in central control rooms, and gave rise to "distributed" control systems (DCS), pioneered by Honeywell with its TDC 2000. But, these were not really "distributed" because they were still relatively large clumps of computer hardware and cabinets filled with I/O connections. The arrival of the PC brought low-cost PC-based hardware and software, which provided DCS functionality with significantly reduced cost and complexity. There was no fundamental technology innovation here—rather, these were innovative extensions of technology developed for other mass markets, modified and adapted for industrial automation requirements.

On the sensor side were indeed some significant innovations and developments which generated good growth for specific companies. With better specifications and good marketing, Rosemount's differential pressure flow-sensor quickly displaced lesser products. And there were a host of other smaller technology developments that caused pockets of growth for some companies. But few grew beyond a few hundred million dollars in annual revenue.

Automation software has had its day, and can't go much further. No "inflection point" here. In the future, software will embed within products and systems, with no major independent innovation on the horizon. The plethora of manufacturing software solutions and services will yield significant results, but all as part of other systems.

So, in general, innovation and technology can and will reestablish growth in industrial automation. But, there won't be any technology innovations that will generate the next Cisco or Apple or Microsoft.

We cannot figure out future trends merely by extending past trends; it’s like trying to drive by looking only at a rear-view mirror. The automation industry does NOT extrapolate to smaller and cheaper PLCs, DCSs, and supervisory control and data acquisition systems; those functions will simply be embedded in hardware and software. Instead, future growth will come from totally new directions.
New technology directions

Industrial automation can and will generate explosive growth with technology related to new inflection points: nanotechnology and nanoscale assembly systems; MEMS and nanotech sensors (tiny, low-power, low-cost sensors) which can measure everything and anything; and the pervasive Internet, machine to machine (M2M) networking. Real-time systems will give way to complex adaptive systems and multi-processing. The future belongs to nanotech, wireless everything, and complex adaptive systems.

Major new software applications will be in wireless sensors and distributed peer-to-peer networks – tiny operating systems in wireless sensor nodes, and the software that allows nodes to communicate with each other as a larger complex adaptive system. That is the wave of the future.

The fully-automated factory

Automated factories and processes are too expensive to be rebuilt for every modification and design change – so they have to be highly configurable and flexible. To successfully reconfigure an entire production line or process requires direct access to most of its control elements – switches, valves, motors and drives – down to a fine level of detail. The vision of fully automated factories has already existed for some time now: customers order online, with electronic transactions that negotiate batch size (in some cases as low as one), price, size and color; intelligent robots and sophisticated machines smoothly and rapidly fabricate a variety of customized products on demand.

The promise of remote-controlled automation is finally making headway in manufacturing settings and maintenance applications. The decades-old machine-based vision of automation – powerful super-robots without people to tend them – underestimated the importance of communications. But today, this is purely a matter of networked intelligence which is now well developed and widely available.

Communications support of a very high order is now available for automated processes: lots of sensors, very fast networks, quality diagnostic software and flexible interfaces – all with high levels of reliability and pervasive access to hierarchical diagnosis and error-correction advisories through centralized operations.

The large, centralized production plant is a thing of the past. The factory of the future will be small, movable (to where the resources are, and where the customers are). For example, there is really no need to transport raw materials long distances to a plant, for processing, and then transport the resulting product long distances to the consumer. In the old days, this was done because of the localized know-how and investments in equipment, technology and personnel. Today, those things are available globally.

Hard truths about globalization

The assumption has always been that the US and other industrialized nations will keep leading in knowledge-intensive industries while developing nations focus on lower skills and lower labor costs. That's now changed. The impact of the wholesale entry of 2.5 billion people (China and India) into the global economy will bring big new challenges and amazing opportunities.
Beyond just labor, many businesses (including major automation companies) are also outsourcing knowledge work such as design and engineering services. This trend has already become significant, causing joblessness not only for manufacturing labor, but also for traditionally high-paying engineering positions.

Innovation is the true source of value, and that is in danger of being dissipated – sacrificed to a short-term search for profit, the capitalistic quarterly profits syndrome. Countries like Japan and Germany will tend to benefit from their longer-term business perspectives. But, significant competition is coming from many rapidly developing countries with expanding technology prowess. So, marketing speed and business agility will be offsetting advantages.

The winning differences

In a global market, there are three keys that constitute the winning edge:
Proprietary products: developed quickly and inexpensively (and perhaps globally), with a continuous stream of upgrade and adaptation to maintain leadership.
High-value-added products: proprietary products and knowledge offered through effective global service providers, tailored to specific customer needs.
Global yet local services: the special needs and custom requirements of remote customers must be handled locally, giving them the feeling of partnership and proximity.

To implementing these directions demands management and leadership abilities that are different from old, financially-driven models. In the global economy, automation companies have little choice – they must find more ways and means to expand globally. To do this they need to minimize domination of central corporate cultures, and maximize responsiveness to local customer needs. Multi-cultural countries, like the U.S., will have significant advantages in these important business aspects.

In the new and different business environment of the 21st century, the companies that can adapt, innovate and utilize global resources will generate significant growth and success.

REFERENCE

- Jim Pinto, Fully automated factories approach reality [Online], Available: AutomationWorld.com
- Industrial robot management [Online], Available: www.9engineer.com

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