Building Flexible Manufacturing Systems for the Changing Industrial Landscape

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Introduction

The industrial environment has reached a phase of continuous instability and fast-paced changes. Changing customer needs, shorter product life cycles, geopolitical instabilities, and increasing unpredictability in the supply chain have led to realization of inefficiencies in traditional manufacturing processes designed to be highly stable. The need for more adaptive processes that would allow rapid response to the changing needs of the production, demand, and operation processes led to the development of flexible manufacturing systems.

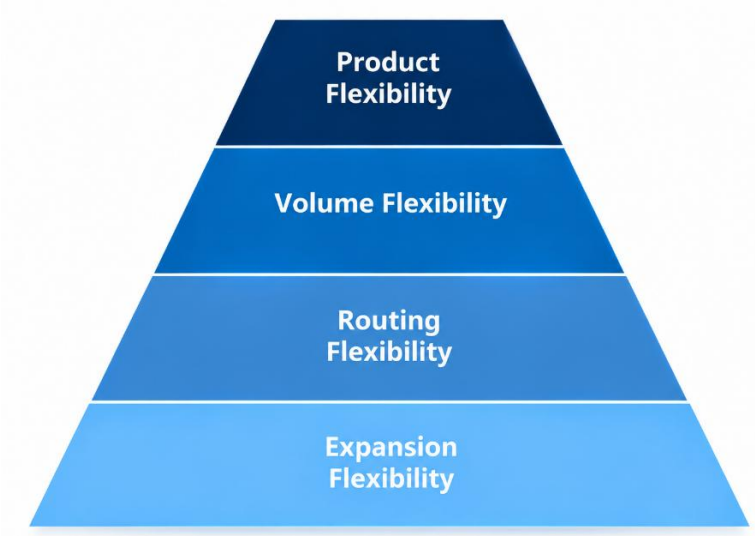

Figure 1: Process overview

This paper will discuss the concepts behind flexible manufacturing systems, technologies supporting the concept, and issues that manufacturing companies need to consider in terms of implementing flexibility in their system operations. Figure 1 demonstrates the hierarchical structure of operational flexibility, showing how expansion flexibility, routing flexibility, volume flexibility, and product flexibility help in building adaptive and scalable manufacturing capabilities.

Why Flexibility Has Become Essential

The traditional manufacturing system, especially the one geared towards mass production of standard products, is based on the premise of stability; however, the premise is becoming obsolete in the modern-day setting.

Shorter product life cycles Product life cycles have drastically shrunk in many sectors because of the fast pace of innovation and changing customer expectations, which force companies to come up with new products more often than was initially intended when designing their production systems.

Demand volatility the consumer tastes have now become more segmented and inconsistent, hence necessitating the producers to cope with greater product variety and more frequent changes in demand for different products.

Supply chain disruption the fragility of highly efficient and just-in-time international supply chains has been shown several times by geopolitical unrest, natural catastrophes, or other unexpected occurrences, thus highlighting the importance of manufacturing operations that can respond rapidly to changes in the availability of resources.

Mass customization expectations Growing customer demands for customized products have led to a requirement for manufacturing systems that can produce smaller quantities of very diverse products at an economic cost, rather than large quantities of standardized products produced by mass production systems.

Defining Flexible Manufacturing Systems

Flexible Manufacturing System (FMS) is a system that is able to adapt itself efficiently to changes in the kind of products being produced, their quantities, and the processes needed, without major changes, downtime, or large investments. Flexibility can be viewed from different angles.

Product flexibility refers to the capacity to produce various kinds of products or product variations through the same production system without having to spend much on conversion time.

Volume flexibility refers to the ability to easily scale up or down the production quantity in relation to changes in demand without losing efficiency.

Routing flexibility is defined as the ability to manufacture a product by adopting various processing routes or machinery sets, which would give one protection from machinery breakdowns.

Expansion flexibility refers to the ability to scale or expand the manufacturing process easily without having to undertake a major overhaul of the current manufacturing system.

Modular and Reconfigurable Equipment

Modular production machinery, developed using standard interfaces and interchangeable parts, makes it possible for manufacturers to modify their production lines to cope with new products or processes faster and cheaper compared to custom-made machinery that demands heavy re-engineering in order to fit new products.

Collaborative and Mobile Robotics

Collaborative and Autonomous Mobile Robots are more flexible compared to fixed automation due to their capability to be re-deployed, re-programmed and re-configured to carry out various tasks quite easily.

Digital Twins and Simulation

The digital twin technology makes it possible for manufacturers to design and simulate other production scenarios virtually without making any changes physically and therefore faster and in a risk-free way assess how to reorganize production processes.

Advanced Manufacturing Execution Systems (MES)

MES systems nowadays ensure that visibility and control can be provided so that flexible manufacturing is managed properly. This includes production scheduling, resource scheduling, and quality control within diverse manufacturing environments.

Additive Manufacturing

The process of 3D printing in industrial operations provides another form of flexibility that allows the creation of customized or small-volume products without the need for tooling costs, which have been the norm for making such customized or small-volume products.

Cloud-Based and Interoperable Systems

Software for manufacturing that is cloud-based as well as standardization of data protocols makes possible the flexible adaptation of the manufacturing systems, where it becomes easier to include new machinery, modify production processes, and collect data from increasingly diverse production environments.

Organizational Dimensions of Manufacturing Flexibility

The development of true flexibility capabilities involves not only the use of flexible technology but also structural, processual, and human resource management considerations that fit into the requirements of a new production system.

Flexible Workforce Skills

For flexible manufacturing systems, it is necessary for the workers to be able to adjust themselves to various types of activities, learn new methods fast, and handle a broad range of problems as compared to the type of problems that could have arisen in case of more conventional manufacturing systems.

Agile Production Planning

The traditional approach to production planning, which is based on stable and long-range forecasts, will have to be replaced by more flexible production planning systems that can cope with shorter planning horizons and more dynamic situations.

Collaborative Supplier Relationships

Flexible manufacturing systems rely on the existence of a very flexible supply chain system. This means that close working relations will have to be developed between the manufacturer and the suppliers to ensure visibility to demand and production information.

Decentralized Decision-Making

Flexible manufacturing settings tend to have more decentralized decision-making frameworks, giving front-line workers and local managers the capacity to make quick changes based on any changes that may occur, as opposed to only using centralized planning and control frameworks.

Balancing Flexibility and Efficiency

While flexibility brings a lot of strategic benefit, it comes at a cost. Very flexible production facilities may be less efficient than dedicated, very high-production capacity facilities focused on a limited number of products. This means that manufacturers have to determine the extent of flexibility that is best suited for the competitive situation that they face, as opposed to aiming at flexibility regardless of circumstances.

The right solution is often a mixed one – having a dedicated capacity for very efficient production of steady and high-volume products and at the same time developing flexibility capacity for handling variable and low volume productions.

Measuring the Value of Flexibility

The problem with measuring the benefits that come from manufacturing flexibility is that the benefits are likely to be seen as savings or revenue protection that could have been lost during times of disruption or shifts in demand. Some metrics manufacturers could use when building a case for flexibility include changeover time and cost, variety of products or product lines that can be made by one production line, ability to respond to changes in demand, and tolerance to disruption in the supply chain and machinery—compared to the risks and costs of alternatives.

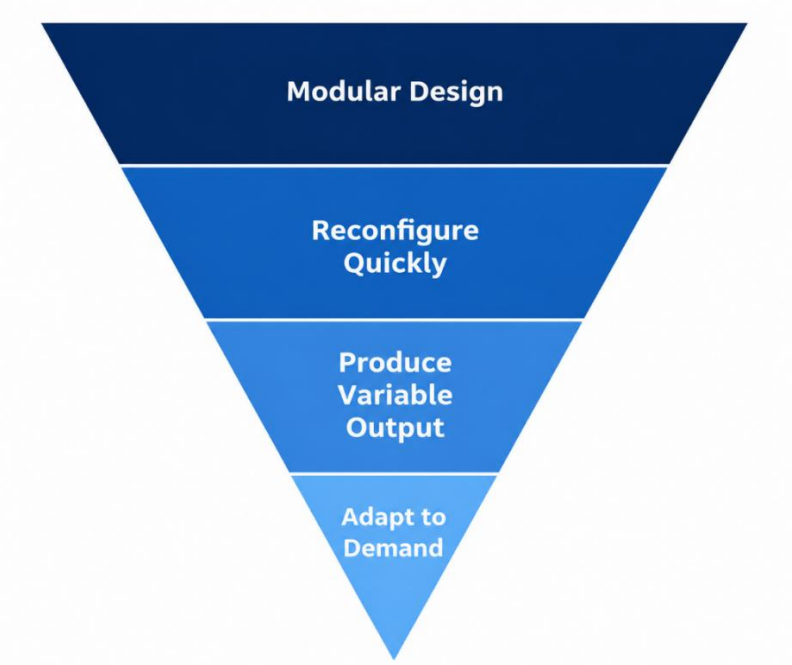

Figure 2: Key framework at a glance

The diagram figure 2 indicates a model for flexible manufacturing system adaptation based on the ability to easily change configuration, varied production capacity, and adaptability according to demand.

Conclusion

Within the environment of a constantly changing industrial landscape, where changes are increasing, the life cycle of the products is decreasing, and there is always some level of uncertainty within the supply chain, flexibility is one of the key attributes for competitive manufacturing enterprises. Investing in the development of modular equipment, robotic collaboration, digital twins, and interoperable production systems, as well as building a flexible workforce and collaborating with suppliers, manufacturers have the opportunity to develop production systems that are able to respond fast and efficiently to the changing product needs, demands, and disruptions. The enterprises that find the optimal balance between flexibility and efficiency will succeed in the volatile environment of the contemporary industrial landscape.