International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 09 Issue 10 ǁ 2021 ǁ PP. 75-79

Beyond Flexible Manufacturing: Mass Customization

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Abstract: *The recent manufacturing environment is characterized as having diverse products due to increased customization, short production lead-time, and unstable customer demand. Today, the need for flexibility, quick responsiveness, and robustness to system uncertainties in production scheduling decisions has increased significantly. Hence, flexibility of the manufacturing systems becomes an important issue which has led to the development of Flexible manufacturing systems (FMS). This unique production system encapsulates various components such as a computer programmed machine tools, automated material handling systems, robots, and Inspection and self-diagnostic facilities into a single production system. This offers a greater product variety; routing flexibility; volume flexibility and so on allowing parts to be processed in small batches as per customer demands.*

In this era of customer driven, manufacturing has to invent new programs and procedures to meet the ever increasing diverse needs of the customers. One such method is "Mass Customization" the ability to successfully market low-cost, high-quality products with short lead times (and in varying volumes) that provide enhanced customer value through customization.

Mass Customization is aimed to provide valued service to the customers in a more efficient manner. This paper analyses the four different approaches of Mass Customization which are collaborative, adaptive, cosmetic, *and* transparent. *This paper attempts to examine the possible insights of these approaches close to the real life flexible manufacturing operations.*

Keywords: *Manufacturing flexibility; Flexible manufacturing system; diverse customer needs; agile manufacturing; Mass Customization;*

Date of Submission: 14-10-2021 Date of acceptance: 29-10-2021

I. Brief overview about FMS

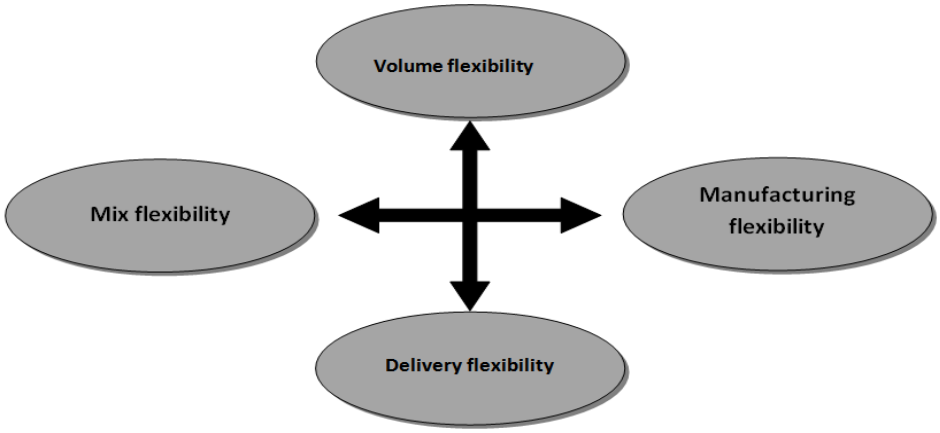
A flexible manufacturing system (FMS) is a manufacturing system in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. This flexibility is generally considered to fall into two categories, The first category, machine flexibility, covers the system's ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second category is called routing flexibility, which consists of the ability to use multiple machines to perform the same operation on a part, as well as the system's ability to absorb large-scale changes, such as in volume, capacity, or capability. Most FMS systems consist of three main systems. The work machines which are often automated CNC machines are connected by a material handling system to optimize parts flow and the central control computer which controls material movements and machine flow. The main advantage of an FMS is its high flexibility in managing manufacturing resources like time and effort in order to manufacture a new product. The best application of an FMS is found in the production of small batches of more product varieties.

The main advantages of FMS are:
Reduced manufacturing times,
Lower cost per unit produced,
Greater labor productivity,
Greater machine efficiency,
Improved quality,
Increased system reliability,
Reduced parts inventories,
Adaptability to CAD/CAM operations,
Shorter lead times
However there are two critical limitations regarding the application of FMS:

Cost to implement,
Substantial pre-planning required

The production of each part or work-piece will require a different combination of manufacturing work stations (WS). The movement of parts from one WS to another is done through the material handling system. At the end of part processing, the finished parts will be routed to an automatic inspection station, and subsequently unloaded from the Flexible Manufacturing System. A typical industrial FMS will have a very heavy data traffic consisting of large files, messages, etc., coming from WS, devices instruments and others.

The concept of flexibility in traditional FMS, which is illustrated in Figure below, has four major components: volume flexibility, manufacturing flexibility, mix ratio flexibility, and delivery flexibility.



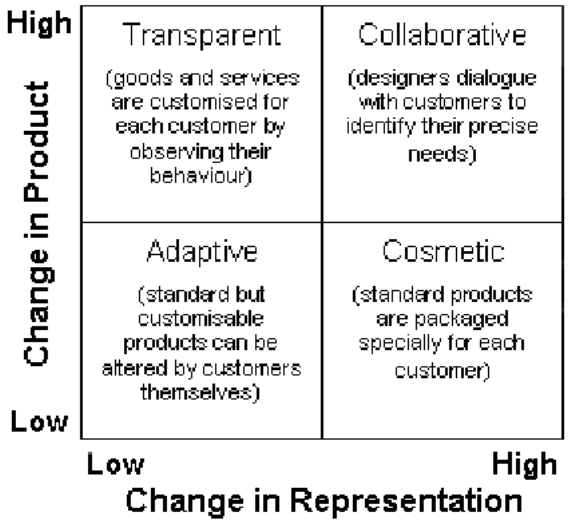
Defining the Four Approaches of Mass Customization

Mass customization relates to the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs. Let's summarize what characterizes the approaches and the conditions under which each should be employed.

Four approaches are:

- **Collaborative**
- **Transparent**
- **Adaptive**
- **Cosmetic**

Let's summarize what characterizes the approaches and the conditions under which each should be employed as shown below:



Collaborative Customization is about **identifying and understanding the range of needs of the customers and then offering them products which match these needs**. Collaboration is done through interaction with customers to figure out the areas where variation is most desired. It allows customers to personalize their own products like in fashion garment industry such as selection of clothing and color, button shape/size and positioning, collar type, sleeve type etc.

Adaptive Customization: Instead of providing customized products, adaptive customizers **create standard goods or services that can easily be tailored, modified, or reconfigured to suit each customer's needs** without any direct interaction with the company. Adaptive customization offers one standard product to the customers along with a few customization options. This approach makes sure that the product is designed in a manner that it can be customized by that it suit to customer needs. The adaptive approach is useful for companies with customers who are looking for a product that serves different purposes under different circumstances. One good example is Tour Operators who offer packages which can be modified to suit customer needs on meals, accommodations, etc.

Transparent customization involves **creating a physically different product for each consumer**. The transparent approach to customization is appropriate when customers' specific needs are predictable or can easily be deduced, and especially when customers do not want to state their needs repeatedly. Transparent customizers observe customers' behavior without direct interaction and then inconspicuously customize their offerings within a standard package. Examples are self-care products such as shampoo, soap, tooth paste and cleaning materials.

Cosmetic customization is to present a standard product differently to different customers.

It is about **packaging the same product in different ways that appeal to different customers**. For example, one can highlight a specific attribute or benefit of the product on one packaging and highlight another attribute on another one.

Thus the Mass Customization demands a higher degree of flexibility than the usual FMS flexibilities.

II. Mass customization manufacturing (MCM) system

Compared with regular FMS, more part varieties are produced in a mass-customized production environment, and manufacturing requirements are often dynamically changed. In addition, customer orders come through more randomly with different delivery dates. Thus, an MCM system must possess sufficient flexibility and rapid response capability to deal with complex manufacturing situations.

The design of an MCM system is an extension of the customer-centered concept in manufacturing. The design goal is to achieve a balance between product standardization and manufacturing flexibility. Success in mass customization manufacturing is achieved by swiftly reconfiguring operations, processes with respect to customers' individual needs and dynamic manufacturing requirements. It is thus critical to develop a manufacturing system that will achieve this goal.

The key to adjusting the manufacturing capability successfully is to reconfigure the system, developing and integrating new functions when necessary.

III. Challenges for Mass Customization Manufacturing

Main challenges of MCM are:

- **Degrees of flexibility**: MCM demands higher flexibility capabilities as is expected to be more flexible enough to respond to small batches of customer demand .This is because installing any new production line is a large investment; current production lines must be able to be reconfigured to keep up with increased frequency of new product designs.
- **Production capability adjustments**: Unlike usual FMS, MCM requires rapid adjustment of production capability based on customer demands. To accommodate ever-changing manufacturing requirements, an MCM system needs to be equipped with rapid, production-plan-configuration and resource-allocation capabilities. Since one of the MCM is to cope with certain level of unknown customized demands, a key objective for the development of an MCM system is continuous satisfaction of customer demand.
- **Modularization methods**: Modularization methods in manufacturing systems usually are often product-oriented, where modules are grouped in teams with intercross functions. It is difficult for such a system to change structures when products need to be changed and production capability needs to be adjusted. In MCM system, it is more desirable to categorize modules based on their functionalities: the greater the diversity of module classifications, the better the system's potential to satisfy different customized demands.
- **Dynamic network-control system structure:** Dynamic and flexible network utilizations in MCM functional modules can maximize the strength of each empowered resource, and hence, the overall risk and

costs are reduced. The dynamic network connections in MCM environment among functional modules should be:
Instantaneous: Accessing valid resources and reconfiguring functional modules should be instantaneous.
Low cost: Besides the initial capital investment, it is better to reduce the recurring system costs.
Seamless: A set of system mechanisms needs to be established to ensure seamless data exchange among customized orders, suppliers, services, and production controls.
Frictionless: There should be no resource conflicts when a new network is created. Success in this feature promotes better cost controls and dynamic network operations.

IV. Application areas of FMS in Mass customized Manufacturing

This paper considers a shop floor control system, having scheduling system for the dynamic decision of job dispatching/next machine selection and tooling schedules and a machine control system for operational control of jobs and tools. In a dynamic scheduling, most of the pre-release function is not performed before the start of a production period, so that machines, parts and tools are not assigned to each other at the planning stage. The dynamic operational decisions with minimal commands from the higher level allow the system to respond quickly to disturbances such as machine failures or demand changes.
To make such dynamic operational decisions and to allow the system to respond quickly to disturbances such as machine failures or demand changes the following data are required:

- the current system time
- the due time of part
- the remaining processing time of part
- the processing time of task
- the ready time at which the last task of part is completed
- the available time at which the last scheduled task is completed
- the expected travel time delay of part (or tool) from its current location to machine
- the estimated start time of task
- the estimated finish time of task

The more suitable major flexibilities as applied for different Mass Customization (MC) approaches currently practiced by the industries are listed below:

Sl No	Required Flexibility	Description	Suitability of application on MC approach
1	Machine	a single machine can process various operations	Collaborative/Adaptive/Transparent
2	Material Handling	different part types can be transported and properly positioned at the various machine tools in a system	All the 4 approaches of MC
3	Routing	different alternative paths can be taken that a part can effectively follow through a system for a given process plan	Adaptive and Cosmetic
4	Volume	system's capability to be operated profitably at different volumes of the existing part types	Collaborative/Adaptive/Cosmetic
5	Process	set of part types that a system can produce without incurring any additional setups	All the 4 approaches of MC
6	Expansion/New Products	different part types that can be manufactured in a system with minor setup	All the 4 approaches of MC

It may be observed many a time manufacturing system combine two or more MC approaches in order to meet individual customers' specific needs.

V. Conclusion

1. Given the present day current business competitive environment and demand uncertainity and ever increasing need for new products, manufacturing companies have to achieve higher productivity & high quality product at low cost to meet different market demands, Mass Customization (MC) has become an important choice of manufacturing strategy to meet this challenge. Agility and quick responsiveness to changes have become mandatory to most companies in view of current levels of market globalization, rapid technological innovations, and intense competition.
2. MC broadly encompasses the ability to provide individually-designed products and services to customers in the mass market economy.
3. To implement MC it is necessary to integrate different manufacturing technologies into a structured framework capable of combining human and technological factors.
4. The four main challenges of MC are to be carefully evaluated for their feasibility on both cost and implementation.

5. This paper presents a literature review on MC. The objective is to identify required conditions and situations where MC implementation is suitable.

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