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INFRASTRUCTURAL BACKBONE OF ENABLING AND CONVERGING TECHNOLOGIES FOR MASS CUSTOMIZATION MANUFACTURING SYSTEM IN AUTOMOTIVE INDUSTRIES

Abstract: *Successful implementation of Mass Customization can result in a challenging manufacturing environment with both high volume production and high product mix, where the customers expect individualized products at the same price they are paying for mass-produced items. Meeting this challenge requires changes in the manufacturing strategies, increase in the flexibility of the production equipments and the most importantly are the adaptable computer systems which make this possible in the manufacturing enterprise.The major requirement is to develop a system which can adapt quickly in order to start new production or to react quickly in failure scenario. Thus the system should have the ability of self improving, self-adaptable and self healing. Thus there is a need for technical migration from a well established flexible manufacturing system (FMS) to intelligent and reconfigurable manufacturing system. This paper describes the major enabling and converging technologies facilitating mass customization manufacturing systems in automobile industries in Indian setting and also discusses the proposed architecture for Mass Customization Manufacturing System.*

Keywords: *Mass customization (MC); Mass customization manufacturing system (MCMS), Manufacturing Strategies; Flexible Manufacturing System (FMS); Intelligent Manufacturing System; Reconfigurable Manufacturing System*

1. Introduction

Technological advances made customers more demanding and overtime they have sought to expect more variety from manufacturers to be able to choose product according to their requirements. This was a very difficult move forcing manufacturers to make a compromise between volume and variety. Increase in the demand pressurised manufacturers to produce products in a shorter time and at less cost. Factors such as shrinking product life cycle increase in product variety and customer expectations on continuous basis have been redefining competition in the market in recent years (Irizarry *et al*., 2001). Mass customization is

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defined as "the customization of products & services for individual customers at mass production price (Davis, 1987). The basic goal of mass customization is "to build customized products, even if the lot size is one, & to achieve customized/cost balance" (Pine, 1993). Hence, mass customization is becoming an important aspect to survive in today's competitive world.

The technologies and processes used for automobile manufacturers have become relatively standard throughout the industry. Furthermore the market has in some respect become saturated and thus the growth in demand is stimulated by innovations that provide distinctive characteristics, while attempting to curtail costs. Indian automobile firms are responding to this challenge through constant innovations in their product and processes. In India future manufacturing systems need to be dynamically reconfigurable to produce customized products in small batches with fast turn-around times in a cost effective manner (Gilke *et al.,* 2011). There is a need to develop the next generation of advanced manufacturing systems that can dynamically respond to customer orders and changing production environment.

In this paper we discuss the various issues regarding the mass customization manufacturing system and propose the architecture for the mass customization manufacturing system. Section 2 refers to the challenges faced by the mass customization manufacturers and, we proceed to discuss the elements of mass customization manufacturing enterprise in section 3. Proposed architecture for mass customization manufacturing system is discussed in section 4. Discussions and conclusion follow in section 5.

2. Challenges

The basic challenge that the mass customization manufacturers face is, 'How much variety to offer, and how much customization to put forward?' Too much customization is not only expensive, but also complicates services and confuses the buyers (Koren, 2010). Implementing mass customization is not an easy task. One of the important challenges with mass customization is that product variety increases drastically with just a few product options. This stretches companies own infrastructure, especially with regard to variety of tooling and fixtures needed to manufacture a wide range of product variants. This also results in complexity to logistics and manufacturing processes. Thus, there has to be trade off between customer satisfaction and manufacturing cost.

The two issues that have to be addressed by any business model for mass customization. The first one is the variety management: how does a manufacturer cope with product variety, and what is the economic upper boundary of product variety. The second is rapid response time: how does a manufacturer supply the buyer's customized orders quickly and in cost effective way.

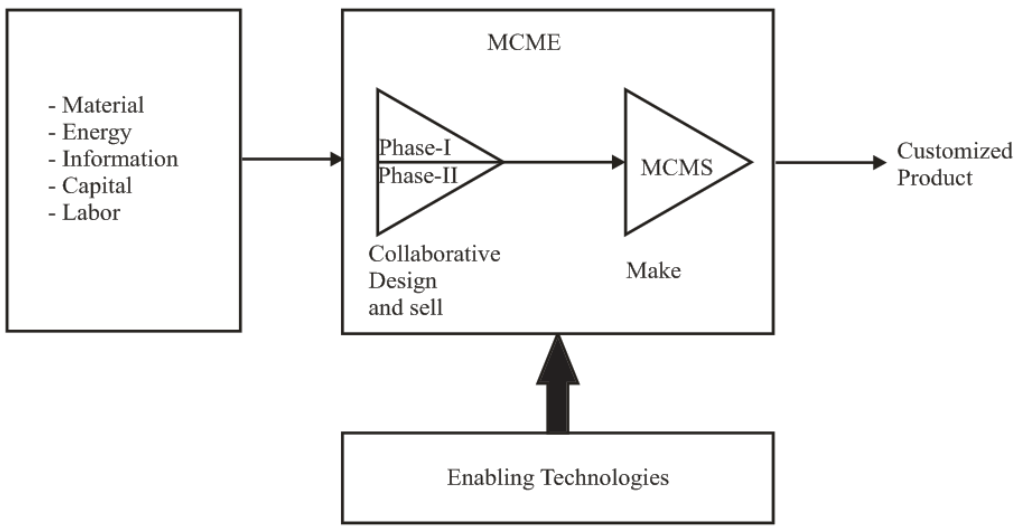
Moving from the current status of manufacturing to the Manufacturing in 2020 will present following challenges: reconfigure manufacturing enterprises rapidly in response to changing needs and opportunities, develop innovative manufacturing processes and products with a focus on decreasing dimensional scale (Bollinger *et al.,* 1998).

Thus the challenge is to design a manufacturing system for mass customization environment capable of delivering high product variety at less cost quickly and accurately.

3. Mass customization of manufacturing enterprise (mcme)

The manufacturing enterprise has three basic elements Design, Make and Sell. The manufacturing companies must develop tools in all these three elements to compete

under the global manufacturing paradigm (Koren, 1999). To be successful, the Mass customization Manufacturing Enterprise must integrate its innovative customizable products with its reconfigurable manufacturing system capabilities and the responsive business model to sell, distribute and maintain a variety of products. The Figure 1 shows the two basic elements of the MCME. The first element is the collaborative design and sells and the second element is the mass customization manufacturing system.



(MCMS=Mass Customization Manufacturing System)

Figure 1. Mass customization of manufacturing Enterprise (MCME)

3.1 Collaborative Design and Sell (CDS)

Product modularity is an enabler of customizable products (Anderson, 2008). The modular architecture allows the company to create product variety at lower cost. CDS has two phases.

Phase I: Modular Design and Open ended Product Architecture. This gives range of product modules. The Open ended product architecture that can be reconfigurable by the customers. These products are contracted and sold.

Phase II: Collaborative and Interactive Design system. The customers will select the modules from phase I, and incorporate the changes as per their requirements, thus finalizing the design. Thus the Product is tailored for specific customer's needs/requirements.

3.2 Conceptual Model of Mass customization manufacturing system

Mass customization manufacturing system can be defined as "a collection of reconfigurable and intelligent machines (or stations) that are integrated to perform a controlled set of operations on raw materials, which alter that material to achieve a desired final form or to assemble a customized product", Figure 2.

3.2.1 Requirement of Mass Customization Manufacturing System (MCMS)

The manufacturing system for mass customization should be developed in such a way that:

- It should be possible to add new components in the system without stopping or restarting the processes.

- It should be able to monitor itself and assess the performance of manufacturing processes, manufacturing unit or subunit.
- It should diagnose the causes of lower performance and take decisions for overall system's performance improvement.
- It should be able to detect the abnormalities, diagnose the cause of failure and take appropriate decisions to recover from them.
- It should be able to adapt the changes of the external business environment, and internal manufacturing environment.
- It should be reconfigurable.

Thus three elements required to shape the mass customization manufacturing system are shown in Figure. 3.

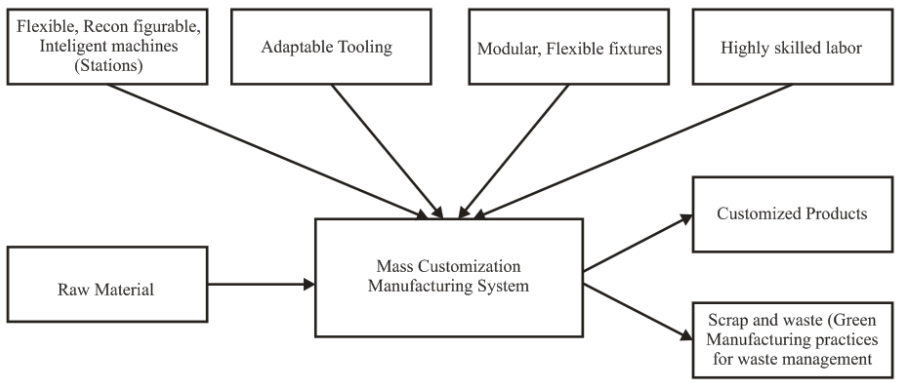
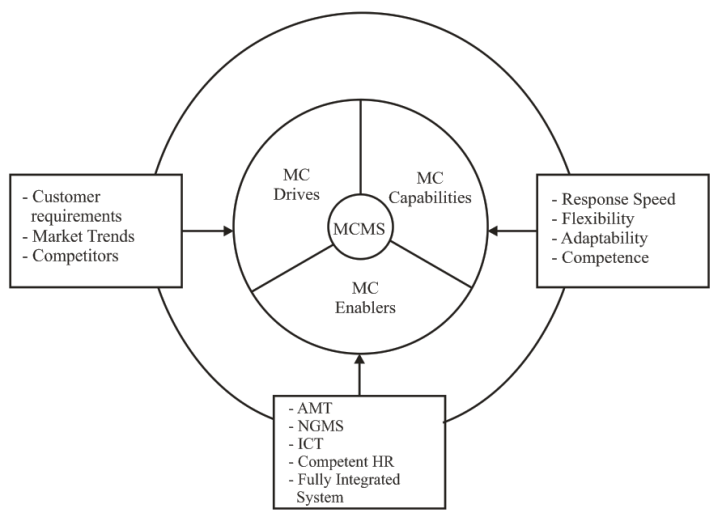


Figure 2. Mass Customization of Manufacturing System



(AMT=Advanced manufacturing technology,
NGMS=Next generation manufacturing systems,
ICT=Information and communication Technology)

Figure 3. Elements of MCMS (Mass Customization of manufacturing system)

1. MC Drivers: Factors that guide and drive the company in the pursuit of MC. Global market conditions allow consumers to be more selective in buying products that fit their various needs. Due to increased customer purchasing power, the trend towards large variety will expand and flourish. The other factors include customer's expectations and desires, market trend, competitors etc.
2. MC Capabilities: Features that the company should seek to become MC enterprise. Modular product design, Reconfigurable product architecture. Response speed, flexibility, competence etc.
3. MC Enablers: Factors available at the company that can provide customized products. Technology enablers: Advance Manufacturing Technology, Next Generation Manufacturing Technology, Reconfigurable Manufacturing System, Competent HR, Integrated Information System and Advanced Management systems.

3.2.2 Technology Enablers for Mass Customization Manufacturing System

Many techniques, tools and technologies developed over the last 25 years facilitate the implementation of mass customization (Dangayach, 2001). These technologies can be divided into two groups, Soft Technologies & Hard Technologies, Soft technologies improve manufacturing infrastructure. They are system oriented and people oriented, inexpensive to acquire and difficult to implement. Hard technologies provide important market qualifying and order wining factory manufacturing outputs. Hard technologies are expensive, they are easy to implement as compared to soft technologies. Engineering purchases them and install them on factory floor. The soft and the hard technologies can be further classified as: Advanced Manufacturing Technologies and Next Generation Manufacturing Technologies, Integrated Information Systems and Advanced Management Systems. The domain of the technology enablers for Mass Customization Manufacturing System is shown in Figure 4. It is the next generation of manufacturing technology required for carrying out work in mass customization environment.

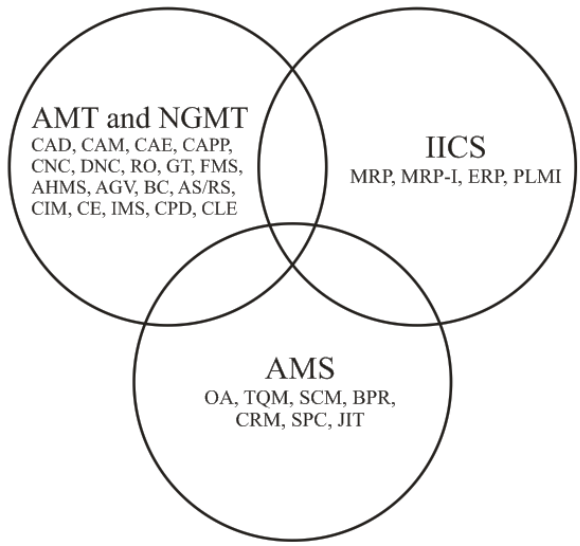
4. Proposed architecture for mass customization of manufacturing system

Figure 5**.** show the proposed architecture for mass customization manufacturing system which consists of total 10 elements.

The Customer requirement (1) is transferred over the internet to the e-product design and order management cell (2). The function of this cell is: Secure and reliable transmission of e-documents and services over the internet between the manufacturing enterprise and the customers. This cell has a collaborative decision support system which will help the customers to decide the product features through e-product catalog and human computer interaction, Reception, creation and sending of order related e-documents, analysis of the customer requirement, product costing and negotiation, development of prototype (using rapid prototyping and virtual prototyping) and final approval from the customer, coordinating with the Mass Customization Management Cell (3) for deciding the quantities to be delivered, payment due dates, delivery due dates etc.

The Mass Customization Management Cell (3) involves automatic and human based activities and coordinates all cells. This cell has a decision support system based on the tools of artificial intelligence to be able to solve the complex decision problems. This takes into account the lack of stability and dynamics, both in the enterprise and surroundings. This cell interacts with e-product design, outsourcing companies, suppliers and the Mass Customization

Manufacturing Cell (4). Based on the order received and the material supplied, the ordered products are manufactured by the Mass Customization Manufacturing Cell (4).



AMT =Advanced Manufacturing Technology, NGMT =Next Generation Manufacturing Technology, IICS =Integrated Information and Comunication System, AMS =Advanced Management System

CAD=Computer Aided Design, CAM=Computer Aided Manufacturing, CAE=Computer Aided Engineering, CAPP=Computer ASSisted Process Planing, CNC= Computer Numerical Control, DNC=Direct Numerical Control, RO=Robotics, GT=Group Technology, FMS=Flexible Manufacturing System, AHMS=Automatic Handling and Material System, AGV=Automatic Guided Vehicle, BC=Bar Coding, AS/RS=Automatic Storage and Retrial System, Cim=Computer Integrated Manufacturing, CE=Cocurrent Engineering, IMS=Inteligent Manufacturing System, CPD=Colaborative Product Development, CLE=Collaborative Engineering, MRP=Material Requirement Planning, MRP-IIManufacturing Resources and Planning, ERP=Enterpises Resources and Planning, PLM=Product Life Cycle Management, OA=Office Automation, TQM=Total Quality Management, SCM=Supply Chain Management, BPR=Business Process Reengineering, CRM=Customer Relationship Management, SPC=Statistical Process Control, JIT=Just In Time Technology

Figure 4. Domains of Technology Enablers for Mass Customization

The Mass Customization Manufacturing Cell (4) receives the input (raw materials) and /or components from the suppliers and finished /semi finished products and components from the outsourced companies and the final customized product(s) are produced by executing specific manufacturing processes. The mass customization manufacturing cell is equipped with artificial intelligence tools and Cax tools (e.g. CAD, CAM, CAP) for planning and manufacturing. The customized products are shipped to the clients, or kept in the warehouses (10).

The outsourcing Management Cell (5) manages the business relationship and the business processes with the outsourced companies. It coordinates the activities of Supplier Management Cell (6) and the Collaboration Cell (7).

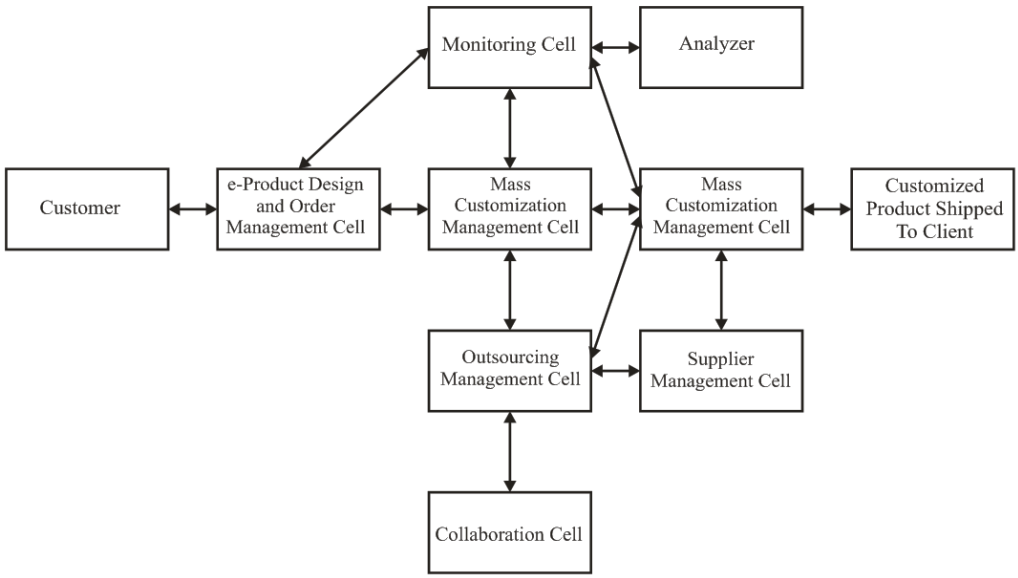


Figure 5. Proposed Architecural Solution For Mass Customization of Manufacturing System (MCMS)

The monitoring Cell (8) tracks the execution of all the cells. It executes a software program responsible for sensing and detecting current status of all the cells (i. e. it gathers the real time data). It monitors all the business process and ensures that all the activities are within the acceptable threshold values. Unacceptable events are informed to the Analyzer (9) which analyses the situation and gives corrective action to the monitoring cell.

5. Discussions

The present approach raises a number of challenges concerning the development of intelligent manufacturing and management system for monitoring, analysis and problem solving tools. Despite the developments in the area of engineering systems and advancements of information and communication technologies, the current manufacturing engineering systems fail to address all the needs of today's mass customization manufacturing enterprise. To develop the system that have the ability of self improving, Self-adaptable and self healing will be one of the greatest task.

In India the automobile industry saw its first sudden increase in growth in 2004 when the information technology boon hit India. The sales almost doubled within a span of seven years indicating the growing economy and better living standards of the people. Business are restructuring and reengineering themselves in response to the challenges and demands of the 21st century. The needs of the customers are highly specific and rapidly changing, although they still want high quality and low cost of product and services. It is essential for the Indian manufacturing companies to be proactive in addressing the challenges related to mass customization.

Machining systems and assembly systems are the backbone of any manufacturing systems. Current trends of manufacturing system are towards enhancing machines with Bio-inspired and human abilities (e.g. Intelligence, Wisdom). This trend motivates a next generation of advanced manufacturing systems that can dynamically respond to customer orders and changing production

requirements. Because of the huge variety of customers orders in MC, the assembly operations in MCMS may be performed by automatic machines, robots, people, or combination of all, but the human assemblers may be the most practical option to accommodate the various needs. The key enabler of MCMS is the Reconfigurable Manufacturing System (RMS) which allows flexibility not only in producing variety of parts, but also in changing the system itself. The technology enablers for reconfiguration are, open architecture controls in software and modular machine tools in hardware. The open architecture controls allow reconfiguration of machine controller, and the modular machine tools offer the customer more machine options (Koren, 1998).

Mass customization is an operational strategy that, if implemented properly, will provide manufacturing products with high velocity. It will also help in quickly introducing new custom high quality products and delivering them with unprecedented lead times. An MCME can only achieve the goals of delivering customized products at mass production efficiency and enhance quality when the two elements of MCME (Design/Sell and Make), are firmly established. The MCME must offer solutions to two basic issues namely variety management and rapid response time.

The system responsiveness, convertibility and scalability are critical concern in MCMS. MCMS requires close interaction among the product development, the manufacturing systems, and the business unit, with a focus on the customer who is at the centre. Thus, successful implementation of mass customization manufacturing system requires serious commitment from top management and workers as well as suppliers.

A wise manufacturer who identifies emerging market and societal needs & knows how to invent a manufacturing system to address these needs will definitely be successful.

Clearly, Darwin's principal-the species that survive are usually not the smartest or the strongest, but the one's most responsive to change. It is applicable to twenty first century manufacturing enterprise. "It is neither the largest enterprise that will survive nor those that have experienced leadership but the ones most responsive to change" (Koren, 2010).

6. Conclusion

Mass customization manufacturing system is the most promising and future oriented of production system development aiming at further automization, optimization and integration of manufacturing processes. In the present approach to MCMS design, it is recommended that MCMS should be created as open architecture and modular structure systems. The open modular architecture system enables MCMS to quickly adapt to the dynamic environment and according to the condition of the enterprise components.

In the present work, a certain conception of designing MCMS was presented. Based on the conception, a methodology for creating the MCMS is being developed. The approach proposed will open up the possibility to build an MCMS using advanced technologies in order to create an integrated environment for implementation of MCMS in automobile industries in India. Fully integrated MCMS will, in near future, enable enterprises to function efficiently and reliably on a global market complying with its rising requirements.

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