White Paper-Trends in technology for cost-effective batch production in General Engineering Industry

Technology Cluster Manager (TCM)

Technology Centre System Program (TCSP)

Office of DC MSME, Ministry of MSME

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Abbreviations

AI	Artificial Intelligence
API	Application Program Interfaces
APICS	American Production and Inventory Control Society
CIM	Computer Integrated Manufacturing
CMM	Coordinate Measuring Machine
CNC	Computer Numeric Control
CPS	Cyber Physics Systems
CV	Carryover Variations
DFM	Design for Manufactures
DMADV	Define Measure Analysis Design Verify
EHS	Environmental Health and Safety
EV	Embodiment Variation
FDM	Fused Deposition Modelling
FGM	Functionally Graded Materials
FMEA	Failure Mode and Effects Analysis
GD	Generative design
I4.0	Industry 4.0
MBD	Model-Based Design
MOM	Manufacturing Operations Management
MSME	Micro Small Medium Enterprises
MTO	Make to Order
NEMA	National Electrical Manufacturers Association
OEMs	Original Equipment Manufactures
PGE	Product Generation Engineering
PLC	Programmable Logical Control
PMI	Production Manufacturing Information
PV	Principal Variation
SEM	Scanning Electron Microscope
TC	Technology Centers
TCM	Technology Cluster Manager
TCSP	Technology Centers Systems Program
TR	Tool Room
VSM	Value Stream Mapping

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1. Introduction

1.1. Background

Technology Centre Systems Programme (TCSP) is a national program undertaken by the Ministry of Micro, Small and Medium Enterprises with the assistance of the World Bank. The program seeks to enhance the technological and skill base of MSMEs in certain manufacturing sectors to improve the competitiveness of MSMEs, via upgraded and new Technology Centres (TCs).

The objective of the program is to enhance the productivity of selected MSME clusters by improving their access to manufacturing technology, establishing a strong focus in providing business & technical advisory services, and improving the availability & employability of skilled workforce through TCs[1]. As part of the program, KPMG has been appointed as the Technology Cluster Manager (TCM) to support TCs and undertake technology and cluster development activities.

The objective of TCM is to increase business opportunities for MSMEs through market linkages, enhance the competitiveness of the cluster business environment, increase the number of MSMEs utilizing the services of TCs, develop a financially self-sustainable business model for cluster related services provided by TCs, identify technologies (Cost Effective Batch Production) of the selected sector for TCs, evaluate existing training programs & develop new training programs for rollout at TCs, conduct a gap analysis of TCs, strengthen the capabilities of TCs to provide technical advises to their clients, increase awareness amongst stakeholders on Environmental, Health, and Safety (EHS) requirements[2].

As part of the project, White Papers in different sectors are being prepared to help identify the future roadmap for the sector in general and the TCs in specific. This White Paper focuses on the trends in technologies for cost-effective batch production in General Engineering Industry.

1.2. Objective, Scope and Methodology

This white paper is part of the engagement of KPMG with the Ministry of Micro, Small and Medium Enterprises (MSME) and aims to provide the latest technologies in cost-effective batch production in the general engineering sector such as leading global technologies, manufacturing techniques, latest innovation in design, technology or manufacturing processes. This white paper also highlights the degree of alignment of the current services of the TC with the market needs and recommend a future course of action for the TC to serve the sector in synergy with the ongoing trends. The TCs will contribute by providing inputs to MSMEs on manufacturing technology & business advisory in these areas. The paper further contains suggestions on the adoption of new technologies in the Automotive Sector by TCs and MSMEs in the cluster.

Scope of this study:

Several newer methods and technologies have been developed, primarily those falling under the umbrella of Industry 4.0 which will alleviate to a large extent the difficulties faced due to the changing market needs, through Batch production. Since resources and energy are finite, new ways of producing more with lesser resources ought to be found. In this context, this

[1] DCMSME website, 25 May 2020
[2] DCMSME website, 25 May 20220

paper discusses the challenges to be addressed and focuses on the technologies, related to novel processes, materials, and information/communication, which could deal with the issues about increased demand for manufacturing goods, finite resources, and environment-conscious production. This paper also examines the details of the emerging technologies and how they can effectively facilitate all manufacturers – especially MSMEs - to adopt them in their manufacturing processes.

The methodology adopted for this study:

A methodology involving seven steps - Fig 1 - has been followed. The major steps are:

- Identifying the market trends and aspirations on product and supplies
- Identifying the most suitable production method to meet those market needs cost-effectively.
- Merits and demerits of batch production methodology
- Trends and technology developments to make small batch production suitable in terms of quality, quantity, timeliness, and cost.
- The advantages and challenges in the newer technologies.
- The way TC and MSMEs need to realign themselves to adopt newer technologies, especially those falling under Industry 4.0
- Identifying a way forward for both TCs and MSMEs.

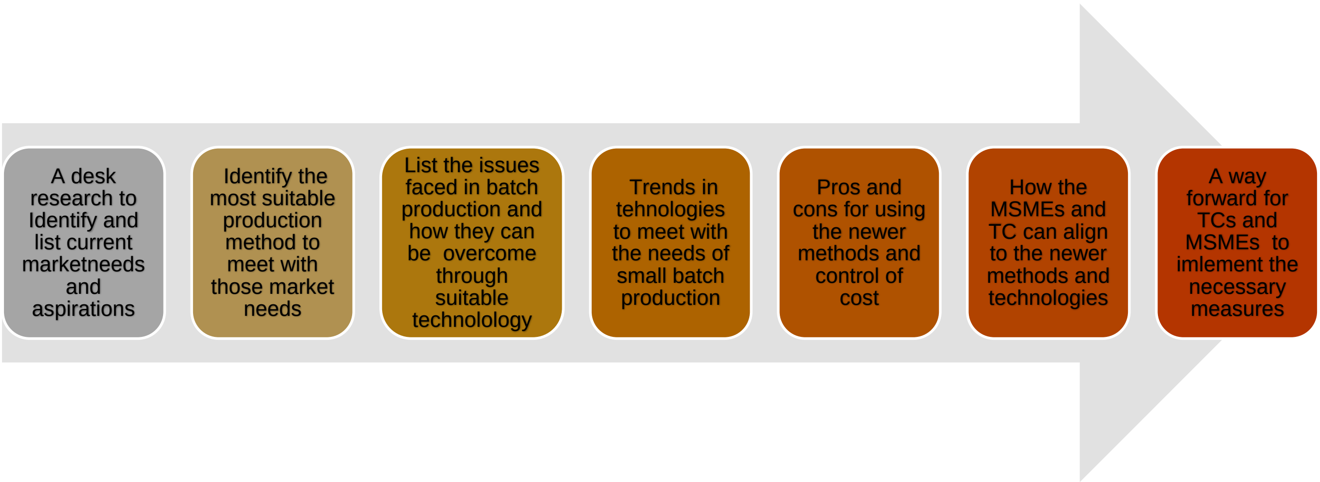


Figure 1: Methodology Adopted

2. Market Overview

2.1. Present General Engineering Industrial scenario

Manufacturing companies all over the world are facing uncertain conditions both relating to market growth and economic sustainability. This is due to ever increasing global competition and changing patterns in the customer demand for high-quality products. The customers are constantly expecting regular updating of features and performance that too allowing razor thin profit margin on products. The manufacturers are compelled to cut down the lead time to deliver newer versions. To remain competitive, companies are continuously looking for ways to reduce production costs. This they aim to achieve by enhancing productivity and by improving product quality. In response to these needs, companies need to adopt newer modified strategies using the available scarce resources judiciously and efficiently. It has also become essential to have a product engineering process to achieve a shorter time-to-market. The market expectation for regular better versions has left no option for the manufacturers other than making small batches of products and bring in newer versions regularly. This reiterates the importance of batch production methodology.

2.2. Production Methodologies

Industrial production methods can be grouped under the following five main types.

- **Project-based production:** When only one number of the product is made and that too only once or limited numbers. Project-oriented items come under this.
- **Jobbing type production:** One or limited quantity but for various jobs /purposes. Small jobbing type shops– both machining and fabrication – specialize in this method. Commonly used for spare parts requirement in the industry, prototypes, manufacture of SPMs etc.
- **Batch production:** Small lots of identical products are made. These lots – consisting of limited numbers - are generally taken up at regular intervals with or without minor modifications in the features. The products are stocked till sales or delivery. This is a method often followed by MSMEs, to supply the requirements of various OEMs.
- **Mass production:** Used when large quantities of one item with the same dimensional features, tolerance and finish are to be made, generally on a fixed production line. Production of automobiles, white goods fall under this category.
- **Continuous Production**[3]: Continuous flow production resorted to when many thousands of tons of same and identical products are made. Production of steel, other metals, metal sections fall under category. The process is highly automated, and few workers are required.

The features of different production methods are summarised in Table 1.

Features	Production Methodology				
	Project-based	Jobbing	Batch	Mass	Continuous
Quantity produced at a time	Limited as per project needs	Small numbers	Flexible Batch size	Large	Very Large

[3] The difference between continuous and mass production is that in continuous flow, the production line is kept running 24 X 7 X365 days during the year. This will help to maximize production and eliminate the extra costs of intermittent on and off the operation except for planned maintenance.

Features	Production Methodology				
	Project-based	Jobbing	Batch	Mass	Continuous
Variety of parts	Possible	Possible	Needs to be planned	Generally, not possible	Not possible
Frequency of supply	Once only	Repeated at different intervals	At planned intervals and periods	Regular and continuous shifts	Non-stop and continuous 24*7
Labour required	Medium	Low	As per requirement	High	Medium/Low
Quality	controlled for each part	Controlled for each lot	Can be tightly controlled through different strategies	Controlled through sampling	Controlled through process parameters
Initial Investment	High	Low to Medium	Low to medium	High	Very high
Type of component handled	One-off special item	small batch assembly	Regular batch assemblies	Large requirements of identical parts	Exceptionally large turn over in number
Allow automation of the process	Not possible	A little and allows low-cost automation	Ideal for low-cost automation	Can allow full automation	Full automation is essential
Best suited to	Large fabricators/machine shops, corporations	Machine tool assembly	Engineering goods, auto components, defence, and aviation parts	Automobiles of all types, white goods	Steel and other metal production

Table 1: Features of various production methods

The different available production methodologies along with the product areas where they are suited and workable are depicted in

Figure *2*. Each production method is best suited to one type of requirement – with respect to quantity, design changes and minor variations in features.

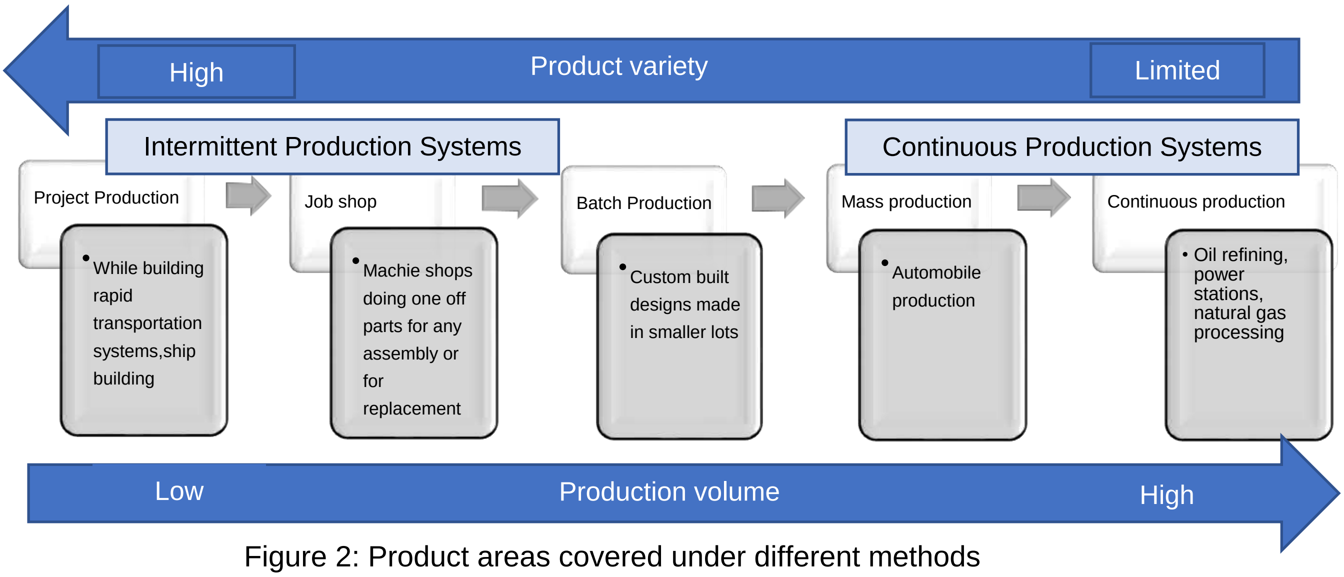


Figure 2: Product areas covered under different methods

3. About Batch Production

Batch production is defined by American Production and Inventory Control Society (APICS) “as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing. A batch is a selected number of different parts that are taken up for production.”. Batch production is often used in low-volume diversified manufacturing and is gaining importance due to the major trend of product customization[4]. It is characterized by the manufacture of generally pre-determined number of products, produced at regular intervals and stocked. The subsequent batch is taken up after the batch on hand is sold. All the parts of the same batch follow the same manufacturing path, but each part receives its operations.

In batch production, the same production equipment is used to make different batches of different items at different times. However, in case of batch production using reconfigurable manufacturing systems, the machine modules can be rearranged to allow a variety of operations without changing the settings. These changes are done based on the operational needs for a particular batch. However, the configuration is not changed while producing parts of the same batch. The reconfiguration is done when such changes are needed between two different batches.

3.1. Merits and demerits of Batch Production

Small batches provide a flexible and lucrative way to build parts and assemblies[5]. In batch production, the errors can be rectified between production rounds to continually improvise on the yield. Also, extra features on the part can be added for each batch. Once a batch gets started and the same can be used to test the waters – the market - without committing to a large inventory.

[4] Optimal Cost Design of Flow Lines with Reconfigurable Machines for Batch Production Olga Battaïa, Alexandre Dolgui, Nikolai Guschinsky
[5] Role of batch size in scheduling optimisation of flexible manufacturing system using generic algorithm- Mohammed Umair Akthar, Mohammed Huzaifa Raza and Muhammed Shafiq

Batch production has a few inherent issues as well. This type of production calls for a very stringent control on the operating parameters to ensure that there are no performance deterioration control methods, between the batches. Latest developments of new measurement technologies shall be necessarily incorporated to ensure consistent product quality. This can be done only through online measurement[6]. The other area that poses the major issue in batch production is "scheduling". Due to the small run of each batch, a closer control on scheduling needs to be installed in the factory. Another is needing special care is to do it all again in a way that can retain the cheapness, convenience, and effectiveness but at the same time retaining the sustainability.

Overall, the advantages outweigh the disadvantages of batch production. Once the prototype is rigorously tested, the batch production is most cost-effective. Currently, the batch production system is used under the following circumstances[7]:

- For short production runs of a same part.
- Batch production is suitable when the available machines are flexible in processing.
- When the same set of plant and machinery are installed and used to produce different products.
- In cases where the Job order takes up more time the estimated time and cost compared to batch production.

3.2. A relevant method for MSMEs

MSMEs are engaged primarily in one or maximum two products made in small or large batches – as per the schedules given by the OEMs. With the recent fluctuations in the auto and transportation industries, it has become more and more necessary for the MSMEs to take up multiple products or deviations in design for a range of products. This point reconfirms the suitability and adoption of batch production among MSMEs.

4. Changing expectations and challenges faced by the Engineering Industry

4.1. Expectations

Market Expectations: The market has several expectations for the products covered by the engineering industry.

- Newer innovative designs: Market's primary expectation is to introduce new designs with customer-friendly features and aesthetics. It expects a range of quality products to choose in a limited time span. In some cases, the customer insists on "On-time delivery" though the order is a custom oriented one and it warrants make-to-order (MTO) manufacturing procedures. In that event, methodologies like "Design for Manufacturing" (DFM) can be used.

[6] Run-to-run control of batch production process in manufacturing systems based on online measurement, computers, and industrial engineering volume 120, March 2020.

[7] International Journal of Engineering Applied Sciences and Technology, 2020 Vol. 5, Issue 2, ISSN No. 2455-2143, Pages 78-86 Published Online June 2020 in IJEAST

- Light, compact, aesthetically attractive: Parts and assemblies to be light and compact. Compact miniaturized designs with good aesthetics are the expectation of the end-user and the market reflects the same.
- Needs a variety to select: The market expects a variety of designs with varied features and performances. Customer needs a basket of accessories to select from.
- Shortest delivery time: The expectation is to get supplies within the shortest delivery time. The order completion time on several factors including incoming material arrival, its variability in terms of production parameters, and the size of the batch planned. Even among those, batch size has now become incredibly significant as the market does not want to hold a huge stock of inventory and the associated costs.

Expectations of Manufacturer:

- Smaller batch production: The manufacturers want (i) fixed batch quantity and size, (ii) a minimum number of parts in each sub assembly or assembly and (iii) the number off in each batch shall be an optimal one.
- Need newer Technology and methods: It is scouting for technologies that can reduce the development time, prototyping time, testing time and introduction time to market.
- Higher dependence on data and systems: The manufacturer wants to use commercial software to handle data. This will help to enhance the resolution of the design and using IoT based digital data to provide operating parameters and variables of the systems.
- A fortified supply chain to assist in realizing the user satisfaction: The engineering industry is becoming dependent on fully data driven. They make the design to meet the outcome expected by the market. So that both the manufacturer and the market move hand in hand in their expectation, data need to flow constantly between all the players – input suppliers, component supplier, assembler, distributor, user. This has become possible with the digitalization of the manufacturing activity. Due to digitalization all concerned in the supply chain are aware of the progress, issues, challenges on a live basis. This ultimately helps the user. User satisfaction is the goal.
- Efficient and good quality processes: The technology and process shall ensure Low rejection and reworking.
- Less overheads: The manufacturer is looking for technologies that will help to reduce the avoidable staff – especially in the monitoring and controlling the flow of operations and output. Upskilling is a key goal for businesses rather than reducing employment
- Quick turnover of product cycle: They are constantly on the lookout for newer technologies to ensure that the product cycle time is reduced to the minimum.
- Importance for Innovation and creativity: Till recently the industry has used established traditional practices. With the stress on innovation and adaptation they are now required to move to interdisciplinary engineering teams having a large spectrum of intellectual abilities. Exposure to Technology and their associated creativity are basic ingredients needed in manpower, in the industry.

Government:

- Energy and resources conservation: Irrespective of whether a product can bear or not – resource conservation at all levels has become the key watchword for the government.
- Environment friendly manufacturing and product: From the Government's perspective, the government wants the manufacturers to focus both on product performance but also on impact on environment. They want the industry to go in for environment friendly methods and processes.

- The nation wants to become a hub for global supply: The governments now attach a great importance for technological innovation and excellence. This has been the experience of several countries. The three watchwords -Technical competence, innovation, and environment friendly production - alone help a nation in becoming a global hub for parts supply. That approach alone can ensure the nation's prosperity and security in this dynamic market conditions. So, the nation wants to cruise towards making India a global supply hub.

The above-multisided expectations at the lowest possible cost have given birth to several newer techniques in each area of the production activity. The technology trends to effectively achieve cost control and market objectives are tabulated below under each of the activities involved in the product generation cycle. The changing demand trail has set a cycle of action wherein one is driving the other as shown in Figure 3.

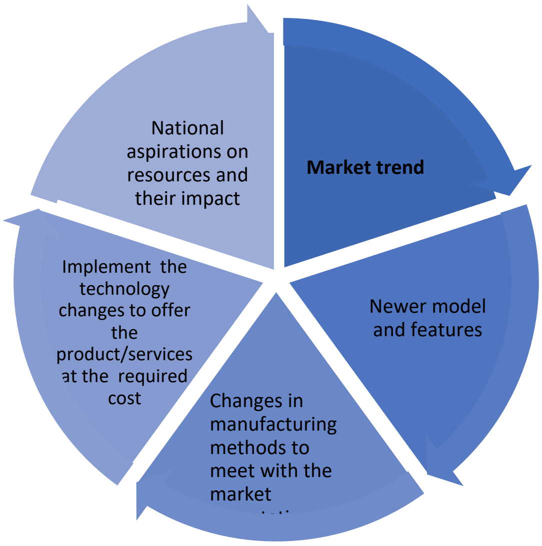


Figure 3: Demand Trail

4.2. Challenges faced by the manufacturers in the sector

The challenges faced in time reduction in developing the prototype and the cost of individual parts can be translated and divided into challenges posed in each of the steps involved in the product generation cycle.

Activity	Challenges faced
Design	• Ability to give design and drawing details from a functional part direct • Ability to carry on design and production simultaneously to reduce difficulties in manufacturing • Use of Newer – lighter, energy-efficient Material • Maximum use of components off the shelf in the design • Simulation techniques to understand the product and its behaviour right at the design stage • Ability to visualize performance in the field at the design stage itself • Use of methods such as "Design for Manufacture" in order to bring down production costs

Activity	Challenges faced
Prototype Production	• Facility to produce with minimum tailor-made tooling • Ability to make one number to test the product cycle • Use of identical methods in producing for both prototype and subsequent small batch production
Testing the prototype for approval	• To carry out Remote testing • To facilitate Frequent and early testing
Manufacturing	• To use Lean-Six Sigma based production • To avail Concurrent engineering • Use the principles of the Theory of constraints • Carry out Live follow-up
Product Introduction cycle	• Align to the Change in concept from Raw material to market to womb to tomb – a full cycle • Avail of Six Sigma based DMADV technique for solving the issues /problems like rejection rate, quality inconsistencies, resource utilization right from the design stage

Table 2: Challenges faced by Manufacturers

5. Newer solutions and technologies

This section outlines the new solutions that are being introduced in various stages of the Product manufacturing cycle – starting from design covering up to delivery to customer. These solutions resort to Industry 4.0. The primary objective is to safeguard the competitiveness of manufacturing.

At its core, Industry 4.0 resorts to cyber-physical systems. This tantamount to the merger of physical and virtual worlds. It helps to replicate the physical world in the virtual one, assist in data collection, processing the data collected , carrying out the needed analytics on the data , communicate the results based on that analytics in a easy format and based on that to interact with all the players involved in the manufacturing chain. These technological foundations allow three central characteristics[8]:

- Horizontal interconnection: This refers to digital interconnection across the company boundaries including the entire supply chain.
- Vertical interconnection: This covers the interconnection within the enterprises between various functions.
- End-to-end Engineering: It covers the interconnection between product development, production, usage, and recycling i.e., the entire product life cycle.

While a few solutions are available, the selection of a methodology shall be based on – the need, time available for execution, cost of adopting the newer method, the skill of the operatives. These newer technologies that are coming into the market will meet the challenges posed by batch production in one way or the other. They cover the full spectrum of the “product cycle” starting from design till after-sales service – i.e., design, prototyping, manufacture, inspection, quality control, testing, delivery to market, maintenance along with other aspects like market price forecasting for RM procurement, environmental impact and Training.

[8] Manufacturing design technology. Industry4.0 Carolina Machado, J Paulo Davies

5.1. Newer trends in Designing

Competitive market pressures are on the increase and requires a short innovation cycle, more versatile products with newer frills and features, flexibility in terms of the time taken up for production. To achieve the above, the trend is to use virtual prototyping methods right from the early stages of the designing process. This paper brings out 3 newer methods in Design. They are Generative design, interactive system design and Model-based design.

5.1.1. Generative Design

During the design process, designers shall take decisions on the preferred final shape, geometry of the product , a product that is ergonomically compliant, a few alternative materials in which the required part can be made , physical characteristics of the product , anticipated life of the product. etc, to name a few. The combination and the available variants in each of these parameters creates a complex problem. To keep pace with the market expectation on timing, the Designer needs to decide on these parameters fast that too accurately. In this effort, advanced systems like generative design are helpful.

Generative design (GD) is a process that will assist the designer to generate a few alternatives and combinations to meet specified criteria, using a specialised software. The generative design process follows a rough conceptual design in the form of a sketch or a 3d model. Then, boundary conditions, safety factors, manufacturing limitations and materials properties are defined. The generative design system generates several potential solutions. The designer can select the design that best fits his need and the customers' requirements. The selection will also consider the cost that the product can bear.

- The major steps involved are: Designers or engineers to give design goals and parameters such as materials, size, weight, strength, manufacturing methods, and cost constraints into generative design software to explore design alternatives. This method uses a software to give the various alternatives.
    - Artificial intelligence (AI) software is used to create over hundreds of design alternatives. Cloud computing power enables the designers to come out with the various alternatives. The designer must input the all the factors, goals, and expectations systematically in the software. That will generate the broad designs. This will help to visualise the final product and based on that the designers can work- out detailed engineering from there.
    - At that stage, the designers or engineers can filter and select the outcomes to best meet their needs.

Case Study - Generative Design

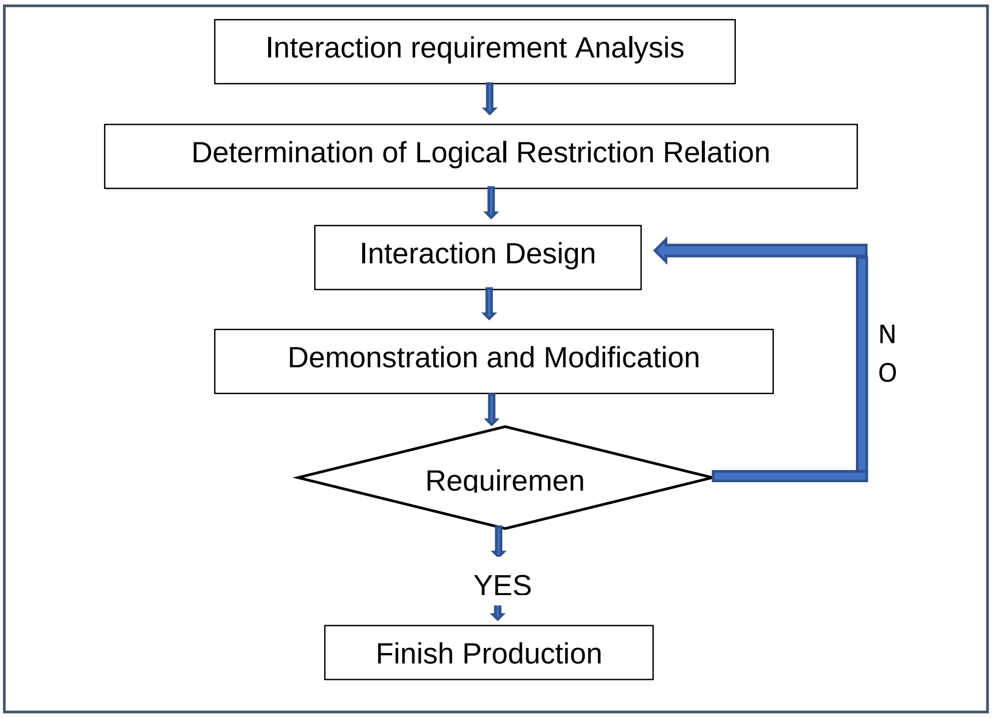
- In the automotive sector in 2018, General Motors started to develop a new series of car components. One of them is a new seat bracket which is 40% lighter and 20 % stiffer than the previous one. The potential solutions were chosen from about 150 different models generated by GD[1].
- In 2019, the company Kartell produced the first commercial chair made using generative design in collaboration with Autodesk and with famous designer Philippe Starck.

5.1.2. Interactive system design

The interactive product design is an extremely useful tool in the development of new and innovative industrial products and processes. In this method the designer takes the help of a specialised software. The software has a lot of inbuilt data stored - relating to material, their properties, technology related information, know-hows that are available and different methods. Based these information and data the product is being modelled, structured, and the same is used offered to the designer. This method gives a choice of very innovative designs.

Interactive design consists of four major stages such as (a)listing the requirements based on the aimed specification (b) actual designing of the alternatives and zeroing in on most suitable specification (c) making the prototype of the selected design and (d) carry out a final design evaluation based on the customer needs. This design methodology is highly iterative. During the design process under this method factors like development, handling, and design of highly realistic, multi-sensorial virtual prototypes for improving decision-making in product design and manufacturing are considered and a suitable one is selected.

The interaction platform is available both in 2D (two dimensional) and 3D (three dimensional) models. With 3D models operations like zooming, rotation, transformation and so on can be easily done for the better visualisation of the final design. For example, the deformation verification[9] of a polystyrene mould can be done using real-time haptic interaction.



[9] Interactive Product design by Xavier Fischer

Figure 4: Sequence to be followed in interactive design[10]

Case Study to bring out User Analysis

- An interactive approach towards product development enables the creation of products that combine optimal performance with effective users' interaction.
- In this work, an additive manufacturing technology that is suitable for manufacturing internal and external accessories of a railcar was developed using an interactive approach.
- The mechanical design of the body kit, which consists of the frame vertex triangle, front threaded and smooth rods, NEMA 17 stepper motor, micro-switch and extruder, was done using the Autodesk Inventor® 2016 while the finite element analysis of its extruder was done using the Commercial Abaqus software 2018.

5.1.3. Model-Based Design: MBD

In practice, engineering parts once designed need some change or the other while it is under production - to suit the process needs, machine capability, deviations in material specifications, minor variations in properties and the actual status of machine loading on a shop floor at a given point of time. Such changes are inevitable especially in a batch production shop. This occurrence is quite common when a new product or a new design is taken up for production.

Till recently the industry was using 2D drawings to define a finished product. When such changes, however minor, are needed on the part it becomes necessary to change the drawing and issue an engineering change" to all departments. In all, several documents must be redone incorporating the changes and recirculated to all departments, to ensure that all departments take note of the changes and act accordingly – for example the departments including inspection, process planning.

While 2D drawings are universally understood, however it can leave some ambiguity on understanding a three-dimensional component. This leads to a few interpretation errors, duplication of instructions. While the issues can be generally solved easily, the fact remains that due to this process, the production and product acceptance get delayed. It also adds to the real cost of the product.

The above issues are resolved in MBD. In this method the designer can give the product details in a 3 D model visually along with the usual dimensional, tolerance and surface finish details of the part designed. Here the part of a model is directly captured and 2D drawings are produced. While the product is under production, the other departments in the manufacturing chain can see and understand the details shown in the 2D drawing.

[10] Interactive Product design by Xavier Fischer

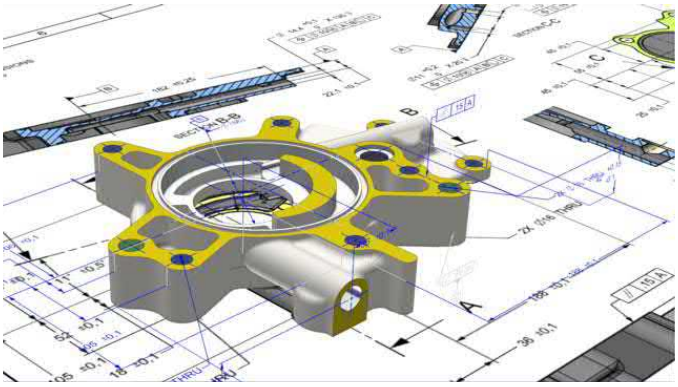


Figure 5: Generation of a drawing from a model

This method truly relevant when minor changes must be made a part to suit a new design. Also, in case the designer wants to gain some time, it can be done using the MBD using the reverse engineering of a similar existing part. This methodology is very useful to MSMEs who are expected to make prototypes based on the 3D sample and often using the principles of reverse engineering.

A major advantage of MBD is that one need not become a software expert to apply these new tools effectively. Even existing functional specialists can use this methodology with utmost ease. MBD is useful for process planning and methods department also. The methods engineer can get the CNC machine program direct from the drawing finalised through MBD.

5.2. New trends in Manufacturing Areas

This section brings out eight newer trends in the manufacturing area - Use of reconfigurable machines, value stream mapping, digitization, Model-based manufacturing, Use of AI, AM, low-cost automation and IIoT.

5.2.1. Use of reconfigurable machines

Often the manufacturing system may use many reconfigurable machines composed of different machining modules (e.g., spindle heads). The use of modules depends on the details of the parts to be produced. When it becomes necessary to carry out multiple operations at the same job preferably on the same job setting, the reconfigurable machines are used. This is a very efficient method for small batch quantities. The number of modules used can go up to four. However, two and three modules are common. Two examples of such machines are shown in Fig no.6. A and B. Fig A is a machine with one vertical turret and two horizontal modules. Fig B gives a machine with two horizontal turrets and one horizontal module.

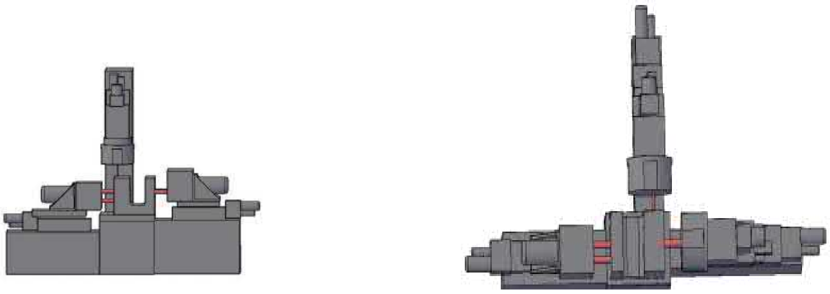


Figure 6[11]: Reconfigurable Manufacturing System (RMS)- A & B

Based on the batch size and the number of batches of various products to be made the designs can be selected.

Cost optimization can be achieved by designing the machining flow lines composed of reconfigurable machines used for batch production[12]. The goal is to minimize equipment cost for achieving a given output and satisfying all the constraints.

5.2.2. Lean Manufacturing Principles for Manufacturing Set-up

Lean Manufacturing Principles use common sense to alleviate manufacturing capacity problems and facilitate improvements in terms of technology, innovation, and small improvements. Three principles generally used are

1. Value Stream Mapping
2. Takt Time
3. Kaizen
4. SMED (Single minute exchange of die)

VSM (Value Stream Mapping) is useful for small and medium enterprises. VSM as a tool gives out the areas for improvement. Use of simulation type models is often resorted to ensure that there is no disruption to regular production. This is of real importance to MSMEs as they can review their operations and alter them to control the cost of manufacture.

Takt Time measures how well the manufacturing system is doing against the customer demand. This can be used in conjunction with the VSM to identify places where cycle times need to be improved. Thus, it leads to innovation and improvements in specific areas.

Kaizen means “change for the better” which could range from very simple improvements to very big projects to address specific problems.

SMED (Single minute exchange of die) is a methodology to reduce the setting up time. Normally changing a tooling takes time. It leads to stoppage of the machine resulting in loss of production. Single-minute Digit exchange of die (SMED) is an accepted alternate way under lean production. Under this method (SMED) the tooling is changed in less than 10 minutes i.e., timing is aimed to be in single digit. This helps to reduce waste and delay in a manufacturing process. This is primarily achieved by resorting to a combination of internal and external operation set up. Also, by carefully selecting the lot size the productivity and cost

[11] Optimal Cost Design of Flow Lines with Reconfigurable Machines for Batch Production Olga Battaïa, Alexandre Dolgui, Nikolai Guschinsky

[12] Optimal Cost Design of Flow Lines with Reconfigurable Machines for Batch Production Olga Battaïa1, Alexandre Dolgui2, Nikolai Guschinsky3

incidence can also be further improved. This is achieved through lower incidence of tooling changeover time per part produced.

Four improvement alternatives are evaluated based on the following three criteria: (1) levelling or optimizing the workforce at the bottleneck operations; (2) Before employing new or additional workforce management, a detailed plan is to be prepared based on the VSM and simulation analysis. (3) Investment in new machines, accessories, and modules to be done purely based on bottle necks experienced, how they would be mitigated. These shall be based on the times and kaizens identified.

5.2.3. Digitization of Production

Digitisation of a production method refers to processes that are interconnected digitally. Digitisation is part of the Industry4.0 principles - to achieve optimisation in cost. resources and time. Digitisation can be done and linked to a SMART process. Under this the organisations digitally communicates with customers, suppliers, and the external environment, using SMART networks. The basic method adopted for digitizing dynamic production processes in enterprises is through simulation. It is done by digitalization of an assembly line and creating a "Digital twin" assembly line.

The trend in the modern factory is to have totally paperless operation using the various techniques of Manufacturing Operations Management (MOM). Manufacturing Execution Systems (MES) is used for this purpose.   Under this scheme, Machines are fitted with embedded computers, AI, and application program interfaces (APIs). The use of these devices makes them suitable for data collection from the operation and to exchange these data using MES. The cloud platform is used for this purpose. The purpose of using Smart Manufacturing is to eliminate manual intervention and the associated inconsistencies, arising out of human inconsistencies. The system is tailored to collect and bring information in a form that can be linked through a digital thread used in automated data exchanges.

The smart factory is the central node in the ecosystem. It uses API requirements for partner and customer interaction. The data exchanges that are used deal beyond the usual purchase order, shipment details, and warranty data while is delivering new data services with the product. For example, if a company is including a product digital twin as an additional service, it must be ready to make accessible to the ecosystem - customer, 3D, and simulation models of the product along with each unit's operational data. The digital twin ensures that data available to all in the supply chain is identical and that all are working on those unified data. This ensures that supply chain operates at its best. Taking corrective action or making changes are based on the collective data and with the full knowledge of the parties linked in the supply chain.

5.2.4. Model-based Engineering and Manufacturing

Model based manufacturing is an extension of MBD. Models are used in coming up with an effective method for exploring, updating, and communicating with the various stakeholders, this helps in cutting down on steps that can be eliminated in the traditional practices. Under this manufacturing scheme model is the key and used as reference in contrast to the conventional systems where in the specially generated 3D drawing or data is the basis for all steps and actions in the manufacturing chain, keeping the model as the central actor the behaviour is simulated in the entire system.

Model-based methods use visualization in contrast to the generated drawing and documentation as the primary guide for all. It is based on visuals to express the information like - design data, the process to be followed, simulation of real behaviour to understand the part to be manufactured.

In model-based engineering, models are used in various domains such as systems, software, electronics, logistics, as well as human behaviour.

There are two types of models: descriptive models and computational models.

- Descriptive models: types of models meant for human consumption and are interpreted by a human.
- Computational models: types of models that are machine-readable and are interpreted by a computer.

Model based system replaces a traditional drawing with digital information of the model or the part. This visual presentation ensures that all data, dimensional needs are all captured direct from the model.

In a manufacturing set up model and associated digital data drive both production and quality processes. These models generally contain dimensional data, tolerances, detailed parts list, material specifications and process details along with the surface finish needs, critical dimensions to be inspected.

5.2.5. Artificial Intelligence - the future of manufacturing

Artificial intelligence is a new technology that is coming up in engineering production. This helps to make manufacturing relatively easy that too at a lower cost. The introduction of AI can make rapid, data-driven decisions, optimize manufacturing processes, minimize operational costs, and improve the way they serve the customers. This augments the human work with easy and ready presentation of facts and data. Globally this is at a very nascent state. A precondition for the use of AI in production is the need for skilling the operatives.

5.2.6. Use of Additive Manufacturing

Additive Manufacturing “AM” is formally defined as the “process of joining materials to make parts from 3D model data, usually layer upon layer”. It is one of the important constituents of Industry 4.0. This technique was initially started for making prototypes fast. Now his technique is extended to making batch production. This technique has high relevance to MSMEs as they can make small batches that are generally expected of them from OEMs. This method when combined with digitalisation makes the control of manufacturing easy, online and based on real time. This will also help the MSMEs to minimise avoidable costs due to supervision and incessant monitoring.

The demand in the market for the introduction of newer models – in automotive, whiteware applications - necessitates continuous preparation of newer prototypes for trial and customer approval. The MSMEs are most suited to carry out such requirements of prototypes. Once the protypes are approved, the initial supplies will be in batches of small numbers. Both for protype production and small batch production 3D printing is the answer. Various major methods that are available under 3D printing are outlined below.

Major Methods	Details
Vat Polymerization	*5.2.6.1* All resin-based 3D printing, in which a liquid photopolymer resin is stored in a vat (as opposed to being ink-jetted through a nozzle), is collectively known as vat polymerization**.** All other names, such as SLA, DLP, or LCD, are subcategories of this technology. VAT polymerization processes use UV light to cure material in a prefilled vat. The following fall under this category. They are *Stereolithography, Direct light processing and Masked stereolithography*
Powder bed fusion	PBF uses a high-energy power source to selectively melt or sinter a metallic powder bed. Melting can be through laser or EBM. The critical factors are the material and the particle size of the material used.
Electron beam melting	The EBM uses powerful electron to selectively melt the powder. The basic requirement of EBM process are Low-pressure, near-vacuum conditions. The electron beam source is on the top of the powder bed. The movement of the electron beam is controlled by a lens system. The system uses a powder hopper that pours fresh powder onto the side of the platform. A new thin layer of powder is coated by a rake on the top, over the previously melted layer.
Direct energy deposition	In this method material and heat input are added simultaneously. The heat input can either be a laser, electron beam, or plasma arc. The material is fed in the form of either metal powder or wire. Due to the vacuum, there will not be high oxidation issues. Laser system requires the introduction of inert gases. Powder DED systems can be either of single or multiple nozzles to eject the metal powders). By using multiple nozzles mixing of different materials is possible to get functionally graded materials (FGM).
Binder jetting	Under Binder Jetting, a binder is selectively deposited onto the powder bed. This bonds the areas together to form a solid part one layer at a time. The commonly used materials are metals, sand, and ceramics that they come in a granular form.
Material jetting or poly jetting	PolyJet consists of small nozzles to deposit droplets of liquid photopolymers onto the build tray. As it is being jetted, the material is simultaneously cured under UV light. The temperature at the tie of jetting is around 30-60°C, this helps to control their viscosity while printing. Parts created using this process require supports to protect the part from deforming or warping and such supports are printed concurrently along with the part. The support material is normally different from the parent material and the supports are knocked out as part of post processing once the part is printed.
Extrusion	Material extrusion (or FDM) is the most popular deposition process for plastic objects.

Table 3: Various technologies under AM

AM uses digitally driven technologies. AM is the start of the digital thread. To manufacture a product AM requires the generation of a CAD file on a CAD software package (e.g., Autodesk Inventor or SolidWorks) installed on the computer. This CAD file can be used to undertake numerical simulations under different conditions (using ANSYS or ABAQUS) to assess the behaviour of the product. This can lead to the development of a digital twin can be used to analyse the product build or other characteristics.

The AM system could be retrofitted with sensors to transfer data wirelessly over the Internet to the digital twin. This will help to improve the process by using in-situ monitoring. Also, it is possible to enhance the quality of the product being manufactured.

The use of big data analytics with artificial intelligence and machine learning protocols can help to significantly improve the quality of AM products with the use of digital twins that can accurately predict issues through simulations. Analysing large data sets requires the use of expensive and sophisticated hardware that can run simulation programs easily. This can be remedied using cloud computing that offers a subscription-based model and can be used for various AM-related tasks e.g., manufacturing, knowledge management, decision support system, and order processing.

The transfer of data over the Internet in a digital format needs to be protected to avoid cyber-attacks that can negatively affect the product being manufactured and could also damage the AM system in operation. The protection of data is also crucial to avoid losing sensitive and confidential information to hackers.

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5.2.7. Low-cost automation

Rationale for automation:

Recent trend of rapidly changing technologies and shortening product life cycles, many companies are focusing on automation as a means for competing in a more demanding market. The purpose of automated systems is to perform functions more efficiently, reliably, and accurately than human operators. Automated systems can often perform functions and tasks at a lower cost than human operators.

To be competitive SMEs with small batch production or tool- and mould-making have already turned to CNC machines and manufacturing processes and computer-based shop floor control. These bring in inbuilt automation in the machine itself. While machining and manufacturing are automated to a larger extent than assembly. It is more difficult to automate due to the complexity of the product and the investment cost in more advanced automation. This is more so in an MSME environment. Among the MSMEs Assembly, packaging, and maintenance are conducted manually to a large extent.

Issues and challenges:

Automation has a few issues too – primarily high cost, need for a set processing line etc. SMEs find it difficult with their product mix to achieve such definiteness on process and methods. However, they want to take the benefit wherever the automation could be introduced.

Crucial parameters:

The key factors to be considered in automation is 1) Product Volume 2) Batch size 3) Number of variants 4) Demand on flexibility. Traditionally, the choice of automation strategy was believed to be a compromise between efficiency and flexibility i.e. if human functions are to be replaced by technology and automation, efficiency will increase, but there is a cost in terms of loss of flexibility. However, this concept is changing. Now the top three most crucial parameters for investing in automation solutions today are investment costs, operating cost, and flexibility.

<u>Low-cost automation as a solution:</u>

Automation gives the necessary support to execute tasks and rationalize decisions. This represents a way of low-cost automation. To run a manufacturing process effectively it is enough if the technology alone is considered. Together with an adequate work-organization wherein human skills can be empowering themselves it establishes the framework for competitive manufacturing in MSMEs. This contribution deals with shop floor-oriented technologies for manufacturing[13]

Low-cost automation is a new strategy that is considered in assembly systems. For example, small robots in combination with collaborative applications involving operator are often cheaper than traditional industrial robot applications, though they are equally efficient. Such low-cost automation needs a thorough study of the existing shop floor operation, the process break - up and identifying the mini areas and actions that can be automated. The automation can also support the worker to improve performance by working in collaboration.

Automation uses sensors for the measurement of key process variables. The development of such new sensors is often a prohibitively costly. In contrast to that in low cost automation e of model-based (or soft) sensors are used as against hardware sensors. In principle, this is generically possible and can be effectively used.

How to select an operation for automation:

To determine the areas to be automated, it is essential to study the operational details and identify and thereafter divide the tasks between operators and robots. The general considerations are given below:

Operations that can be actively considered for low cost automation:

- Heavy lifting or monotonous working operations
- Hazardous tasks for the human
- Big volumes Demands for check of quality
- Tasks that demand high accuracy
- Tasks that demand high repetitiveness

The operations that cannot be generally automated – either through total automation or low-cost automation:

[13] LOW-COST INTELLIGENT AUTOMATION IN MANUFACTURING Heinz-H. Erbe

- Introduction of new product
- Production of occasional products
- Occasional products with a short length of life
- Official Inspection of finished products
- Tasks that demand "feeling"
- Tasks that demand high flexibility

The benefits of low-cost automation /automation:

- Increased efficiency
- Improved quality
- Increased productivity
- Cost-cuts
- Improvement of productivity
- Producing with a minimum of employees

Case Study on a low cost set up for the assembly of a harness connector

In the manufacturing cum assembly unit there was a need for a simple low-cost automation for the assembly of the harness. A novel concept of an assembly automatic machine was designed, having as basis a careful analysis of the functional, productive, qualitative and safety requirements.

This goal was accomplished by task automation, including new components and mechanisms that could perform the desired assembly operations more simply and efficiently than the previous manual production. In fact, through a series of simple but effective mechanical solutions involving automation, it was possible to solve a complex assembly problem.

Although the current description focused on the developed concept, without paying attention to mechanical and automation design details, the equipment was duly designed regarding the mechanical structure, pneumatics, electrical project including graft representation, fabrication processes, assembly rate, economical study, and safety considerations. After the design, the initially proposed objectives were fulfilled:

- Automatic raw material feeding,
- Fully automated assembly process and
- Inspection control to the assembled sets and separation according to the obtained result.

The result is equipment that cancels the need for manual operation during assembly and needs only one operator to feed the raw parts in the vibratory dishes and to collect the assembled or defective products' boxes.

5.2.8. Use of IIoT in Manufacturing

In a production environment it is essential to initiate, collect and exchange data. This is done through sensors on the machines, interconnecting conveyor lines, integrating software and suitable IT infrastructure. In cases where the unit wants to go in for digitisation, suitable dash boards have to be provided. Internet of Things (IIoT) is a system of devices and things that uses the above components to control any manufacturing activity. This technology is referred to as the Industrial Internet of Things (IIoT) that facilitates communication among people, products, and machines. These sensors that are attached to machines and other physical assets on the production floor helps to collate data that influences decisions in real-time. These data are then analysed to corrective action leading to increased efficiency and productivity. These interconnections allow for a better user experience and help in effective decision making. The opportunities offered by IIoT are shown in Figure 7.

To avail of any of these opportunities, the most crucial aspect is the data, therefore, an effective approach to data acquisition and centralization is required. Organizations require reliable data to make informed decisions at every step of the process.

IIoT offers numerous advantages to both consumers and industries:

- Gives data in an unfailing sequence of codes and commands, which can help avoid the commonly accepted issues and human errors.
- Based on the above data, quality of numerous basic activities and systems can be expanded and improved.
- IIoT can convey and decipher information at a level incomprehensible by human knowledge. However, it is offered in simple manner for the user.

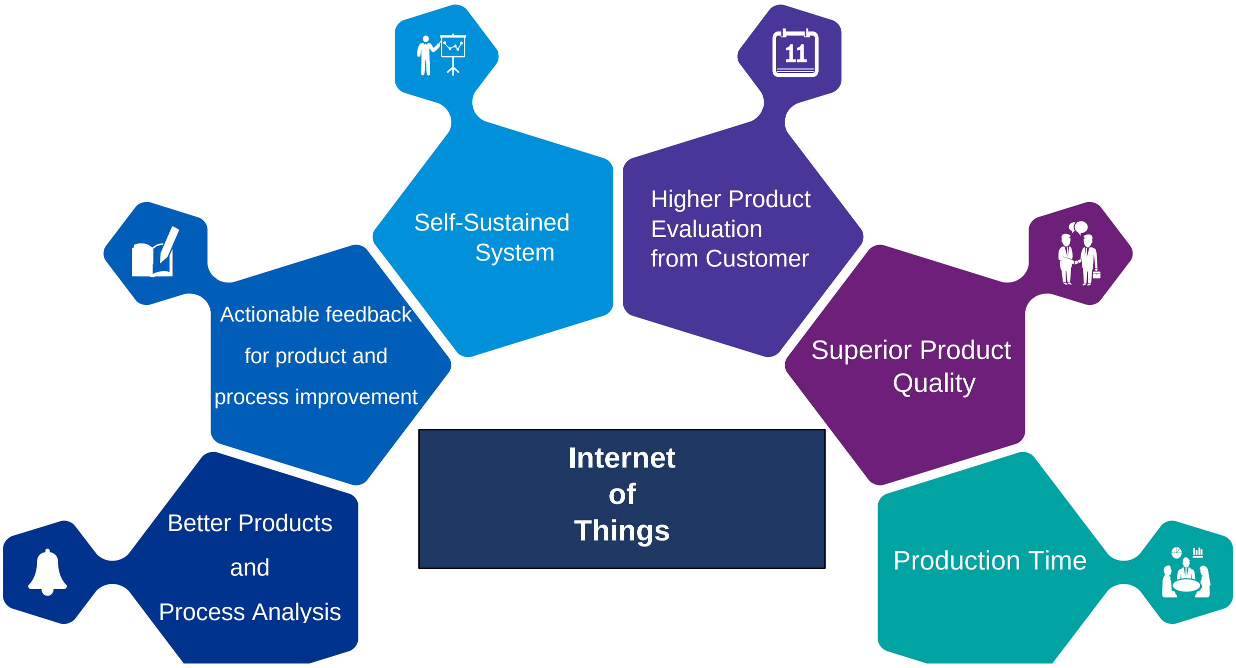

Figure 7: Key outcome through IoT Implementation

5.2.9. Use of AR/VR for MSMEs engaged in batch production

Virtual Reality is computer-based methodology and helps to get a better visualization effects for representing manufacturing systems compared to than any other graphical user interface. This helps users to collect information and based on that quick and correct decisions can be taken. VR can also be used in requirement analysis (RA) while carrying out CIM system development, suitable for MSMEs. This helps to reduce the costs and the time involved at the stage by producing precise and accurate plans, specification requirements, and a design for CIM information systems. These are essentials for small and medium scale manufacturing enterprises. Inspection and QC

MSMEs are keen to ensure that the quality of the product manufactured is monitored to ensure that the defects are identified as and when they happen. Often Some flaws in products are too small to be noticed with the naked eye, even for an experienced inspector.

To overcome this problem, the machines are equipped with cameras many times more sensitive than our eyes to detect even the smallest defects. Machine vision allows machines to “see” the products on the production line and spot any imperfections. The system recognizes defects, marks them, and sends alerts. The trends are twofold – one using a camera and the other using the laser.

The use of the above system can help at all stages of fabrication. The inspection starts from first production phase and ends with the final assembling line. The checking systems uses 3D laser devices, smart cameras, and GO-NOGO gauges for thread, holes, and shafts with tolerances, etc. A major advantage of using this system is that even if gauges are typically manual tools, the digitalization and automation of their report and analysis is done to implement the Industry 4.0 principles.

5.2.10. Other solutions and technologies in Cost effective batch production

Apart from the technologies mentioned in above sections, following major solutions and technologies can be deployed for cost effective batch production in general engineering industry-

- High Speed Machining
- Mixed Reality
- Cloud Computing
- Block Chain
- Energy Efficient Machines & Technologies
- Renewable sources of power like Solar / Green energy
- Smart factories, Building Automation systems
- Zero Waste Campus
- Lean Manufacturing
- Six Sigma
- TPM
- Plasma Technologies e.g. Plasma Nitriding & Plasma Coating
- Water jet machining
- Latest welding technologies e.g. Friction welding, Laser welding, EBW, Magnetic Pulse Welding etc.

5.3. Prediction of failure modes

Reliability of the machines used is an important factor in the manufacturing processes. The failure mode and effects analysis (FMEA)[14] method is dependent upon the experience of experts to determine the primary failure modes and detect the most critical factors for preventing risk.

[14] A novel failure mode and effect analysis model for machine tool risk analysis James J.H.Liou[b]Chun-NenHuang[c]Yen-ChingChuang

Visual inspection and measurement can make false conclusions considering products and processes, Products can fail in a variety of ways, irrespective of the visual inspection. A product that looks perfect may still break down soon after its first use. Similarly, a product that looks flawed may still do its job perfectly well. The way we observe objects and flaws is biased and many things may be different than they seem. With vast amounts of data on how products are tested and how they perform, artificial intelligence can identify the areas that need to be given more attention in tests. Apart from the impact of failure of a component, the expected cost of failure, as a risk element is of great importance to the industry. The critical aspect of an FMEA is updating the failure modes as a continuous process throughout the product life cycle, to ensure that the FMEA becomes the primary source of reference for any quality or engineering team. The proposed model can effectively assist managers in evaluating risk factors and identifying critical failure modes.

5.4. Maintenance

In quality management, both the concepts of “predictive” maintenance and “preventive” maintenance are being introduced. While preventive maintenance focuses on identifying and preventing problems that may occur in the future, predictive maintenance focuses on cost reduction and failure prevention by identifying exactly when parts of a product are likely to cause problems, enabling replacement or repair at exactly the right time[15]

Predictive maintenance is being realized in the form of smart factories based on IoT, CPS (Cyber Physics Systems), sensor technology, and AI technologies.

Predictive maintenance allows companies to predict when machines need maintenance with high accuracy, instead of guessing or performing preventive maintenance. Predictive maintenance prevents unplanned downtime by using machine learning. Technologies such as sensors and advanced analytics embedded in manufacturing equipment enable predictive maintenance by responding to alerts and resolving machine issues.

[15] The quality management ecosystem for predictive maintenance in the Industry 4.0 era Sang M. Lee, DonHee Lee & Youn Sung Kim

5.5. Training

MSMEs, as prominent actors in the industry, are now expected to meet more and more complex customer expectations. With the emergence of the concept of Industry 4.0 the control of production processes by providing real-time synchronization of flows and by enabling the production of unitary and customized products have enhanced. This calls for newer techniques to train the existing manpower (in MSME and other units) and to train the new entrants to the industry. As TCs are engaged in the task of training the engineering manpower, this area needs special emphasis.

There are tools under Industry 4.0 that take advantage of the technologies such as virtual reality and process mining to train both existing manpower and new entrants. Under this firstly, expert workers use an immersive interface to perform assemblies according to their experience. Then, process mining algorithms are applied to obtain assembly models from event logs. Finally, trainee workers use an improved immersive interface with hints to learn the assemblies that the expert workers introduced in the system. The training system, based on process mining and virtual reality, is competitive against conventional alternatives. Furthermore, user evaluations are better in terms of mental demand, perception, learning, results, and performance.

6. Status of the technologies in India and the available opportunities

The status of the various newer and emerging technologies among the Indian Engineering industry is brought out in Table 4 below. Also, the scope for TC and the MSMEs to adopt and avail them are indicated in the same Table. The scope for MSME and TC differ in a few cases, as TCs have a good scope in training the manpower for larger firms as well under their training activity.

Sr.No.	Activity	Technology	Use in India among engineering industries	Scope for TC	Scope for MSMEs to implement
1.	Design	Generative design	Very few big units	High	High
		Interactive system	Not practiced or used	Medium	Medium
		Model-based	Not practiced	Medium	Low
2.	Manufacturing	Reconfigurable machines	Practiced by a few	Medium	Low
		Value stream mapping	Practiced by a few	Medium	Medium
		Digitization	Used by Large firms only	High	High
		Model-based manufacturing	Not introduced in India	High	Medium
		AM	Many units are using, and it is gaining ground.	High	Medium

Sr.No.	Activity	Technology	Use in India among engineering industries	Scope for TC	Scope for MSMEs to implement
		Low-cost automation	Many units are using, and it is gaining ground.	High	High
		Use of IIOT	Over 30% are using for one application or the other	High	High
		Use of AR/VR	Introduced	High	Medium
3.	Inspection and QC	Camera inspection	introduced	High	High
		Laser inspection process	Introduced	High	High
		Prediction of failure	Very few large units follow	Medium	Low
4.	Maintenance	Predictive maintenance	Very few large units follow	High	Medium
5.	Customer service	For servicing and after-sales support	Very few large units follow	High	Medium
6.	Forecasting price	Raw material	Very few large units follow	Medium	Medium
7.	Environmental impact	Wastage generation and control	To be introduced	Medium	Low
8.	Training	Introduction of CDIO	To be introduced	High	Low
		SMART	To be introduced	High	Low

Table 4: Status of technologies in India and available opportunities

7. Impact on cost

The use of one or more of these technologies helps to realize cost reduction and control the time from the receipt of an order up to delivery. The table given below explains the impact of each of these technologies and how they help the batch production.

Sr. No.	Activity	Technology	Outcome	Impact
1.	Design	Generative design	Helps to reduce the product visualizing and designing time.	Order to delivery time is reduced. The cost of designing is reduced.
		Interactive system	Make the designing process user friendly. apart from reducing the product visualization and designing time.	Order to delivery time is reduced. The cost of designing is reduced
		Model-based	This in addition to the benefits of interactive design reduces documentation time	Order to delivery time is further reduced compared to interactive designing.

Sr. No.	Activity	Technology	Outcome	Impact
			normally involved in the designing process.	The cost of designing is reduced which leads to overall cost reduction
2.	Manufacturing	Reconfigurable machines	Setting time reduced Better accuracies achieved	Overall Manufacturing time reduced. Thereby reducing cost.
		Value stream mapping	Identifying the delays in production and the step causing the delay. Accordingly, a suitable machine or man can be employed to reduce production time	Helps to reduce production time and cost.
		Digitization	Helps to control a process live during the process. Helps to reduce the generation of waste and rejection	Rejection and reworking costs are saved.
		Model-based manufacturing	Reduces the processing time in design, planning and manufacturing	Reduces time from order to delivery and thereby cost.
		AI	Visual status of the job and its deviations reduces operation time. Skill for the identification of deviations is passed on to the operator from an expert.	Saving time, it helps to reduce overall cost. Saves expert manpower cost.
		AM	Limited prototypes can be made from CAD drawings.	Saves time and material usage in making unwanted large batches.
		Low-cost automation	Reduces avoidable manpower costs on repetitive jobs. Reduces wastage. Operating efficiency remains high throughout the day.	Reduces cost and ensures the planned operation time including loading and handling.
		Use of IIOT	Online control of the manufacturing operation. Remote control is enabled. Waiting time for correction is reduced.	Cost reduction by reducing the overall cycle time.
		Use of AR/VR	The visual status of the job and its deviations reduces operation time. Skill for the identification of deviations is passed	Saving time helps to reduce overall costs. Saves expert manpower cost.

Sr. No.	Activity	Technology	Outcome	Impact
			on to the operator from an expert.	
3.	Inspection and QC	Camera inspection	Inspection time is reduced. Locates deviations that cannot be easily identified by the naked eye.	Rejection and reworking time reduced. Results in overall timesaving.
		Laser inspection process	Inspection time is reduced. Locates deviations that cannot be easily identified by the naked eye.	Rejection and reworking time reduced. Results in overall timesaving.
		Prediction of failure	Locates likely failure in future	Reduces factory returns and issues due to product warranty and related costs.
4.	Maintenance	Predictive maintenance	Machine availability time is optimized. Ensures trouble-free production.	Ensures planned time delivery.
5.	Customer service	For servicing and after-sales support	Reduces time for attending a part or assembly in case of failure at the customer end.	Reduces factory returns and issues due to product warranty and related costs.
6.	Forecasting price	Raw material	Helps to get the RM at the cheapest price.	Helps to reduce direct material cost.
7.	Environmental impact	Wastage generation and control	Helps to save the environment and ambiance.	Earns the goodwill of the customer and society.
8.	Training	Introduction of CDIO	Planned and distant training possible	product knowledge is given to the user in time. Enhances customer satisfaction.
		SMART technique	Planned and distant training possible	

Table 5: Cost Impact framework

8. Adoption methodology for TCs

Technology Centres focus on basic skilling of manpower to make them ready to participate in the industrial activity. With the changing trends in the industrial and market scenario, added weightage shall be given[16] to the cultivation of engineering practice ability, the comprehensive promotion of engineering quality, the integration of knowledge and technology and the enhancement of innovation ability.

Competencies are to be taught during the training to allow the participants to be prepared for an era in which leadership is changing due to Industry 4.0. Besides a basic understanding of Industry 4.0 technology and leadership as an expected precondition, the necessary

[16] Refer to the developments in Tsinghua University

competencies can be clustered in three interdependent dimensions: communication, transparency, and structure.

From an operational perspective, TCs can cover a wide range of application scenarios in teaching and training. They open new opportunities to carry out process improvements in real production conditions without risk and cost pressure in the production environment.

Regarding the key characteristics, effective and efficient Model factories can be developed in a much more systematic manner. The model factory to be linked with innovations. This can be successfully achieved by integrating the emerging digitization trends into the teaching and training concept of the production system. To further develop the possibilities of model factories, the implementation of digital technologies becomes increasingly important.

Additionally, based on current facilities in the Model factory, more complex product cases and teaching materials will be developed, providing the students a brief insight into how emerging digital technologies have affected product design and manufacturing. Students are to have the opportunity to learn the innovation and entrepreneurial skills so essential for our nation's economic welfare and security, yet this too has been resisted, this time by engineering educators

8.1. Steps to be followed in the adoption of newer technologies

Step 1: Reorganising a model cell within TC:
Set up a model Cell in TC using all or a few of the above technologies with the existing machines and operations. Machines covering all the processes used in their most representative product shall be linked through the digital platform. The TC can use the existing machines like 3axis. 5 axis machine, 3D printer, CMM, robots, storage unit. The TC can link 6 to 7 machines to demonstrate and avail the benefits for their products within the "Model Cell". This will help as a platform for collaboration between researchers, students (trainees) and cluster units. It will also give a real-time depiction of the various processes and advantages to the cluster. The needed investments will be on:

Hardware: interconnecting conveyor lines, sensors on the machines, and IT infrastructure.
Software: Digitization through dashboards, and the integrating software.

The purpose of the Model Cell is:

- The participants to understand the various means of modern Automation such as PLCs, CNC and Robot Control.
- The participants can see the differences between the different communications standards and the different strengths and weaknesses they have and which technology fits for what application.
- The participants will be able to exercise the usage of all shown technologies at their units or workplace.

Step 2: Demonstrate the operation of the Model cell to the MSMEs:
The need of the cluster is to know and to assure itself that Industry 4.0 is not merely for large units. By the above-intended establishment of a "Model Cell," the TC can demonstrate this to the cluster. This will give a new vision to manufacturing units in the cluster about smart factories. It will clear the principle of combining cyber and physical systems. It is appropriate

to mention that setting up this “Model Cell” at TC will cost in the region of 60 lakhs using existing machines. Based on this, Smaller cluster units can emulate the relevant portions applicable to themselves with a smaller budget of 20 lakhs.

Step 3: Prepare the training modules for the following:

<u>High Priority:</u>

- Production Efficiency in Batch production: Through low-cost Automation & Robotics
- Prototyping for new product dev: 3D printing & prototyping lab
- Skilling of manpower: AR/VR & Digitization, newer technologies in designing

<u>Medium Priority:</u>

- Quality Assurance: Through Digitization & AR/VR
- Inventory Management: Supply chain analytics for material planning
- Energy Conservation in batch production: IIoT & Real-time Optimization

<u>Low Priority:</u>

- Inspection Automation: introduction of AR/VR & IIoT for small batches
- Improving Machine Reliability: IIoT & Analytics and its customization to MSMEs
- Introduce training courses for the existing operatives among the MSMEs and for the new entrants.

Step 4: Run Workshops and training programs:

Introduce and offer these training courses to the existing operatives and new entrants to the industry. In workshops[17], they can assess the transferability to their production facilities.

- To be able to understand and use the benefits of cyber-physical systems web technologies are trained generally. In addition, the usage of web standards in collaboration with automation systems is shown, such as web services of a PLC or web services for HMI application (e.g. Tablet Apps).
- The mightiness of such technologies especially for real-time data analysis and predictive maintenance is shown.

Adoption among MSMEs:
Step 1:
Get an orientation in the Model cell and understand the applicability of newer technologies to their specific products
Step 2:
Considering that the product life cycle is getting shorter and shorter, companies should spend a significant amount of time and resources planning new processes and life cycles of factories. To make these processes faster and to lower expenditure on resources, shall be prepared.
Step 3:
Supporting the MSMEs to draw the full benefits of batch production, with the newer technologies This can be realized through IT integration of the production level with the planning level and further on to customers and suppliers. This will cause efficiently and quickly customized products. This IT integration is realized through cyber-physical systems.

[17] Industry 4.0 Learning Factory for regional SMEs Clemens Fallera *, Dorothee Feldmüllera

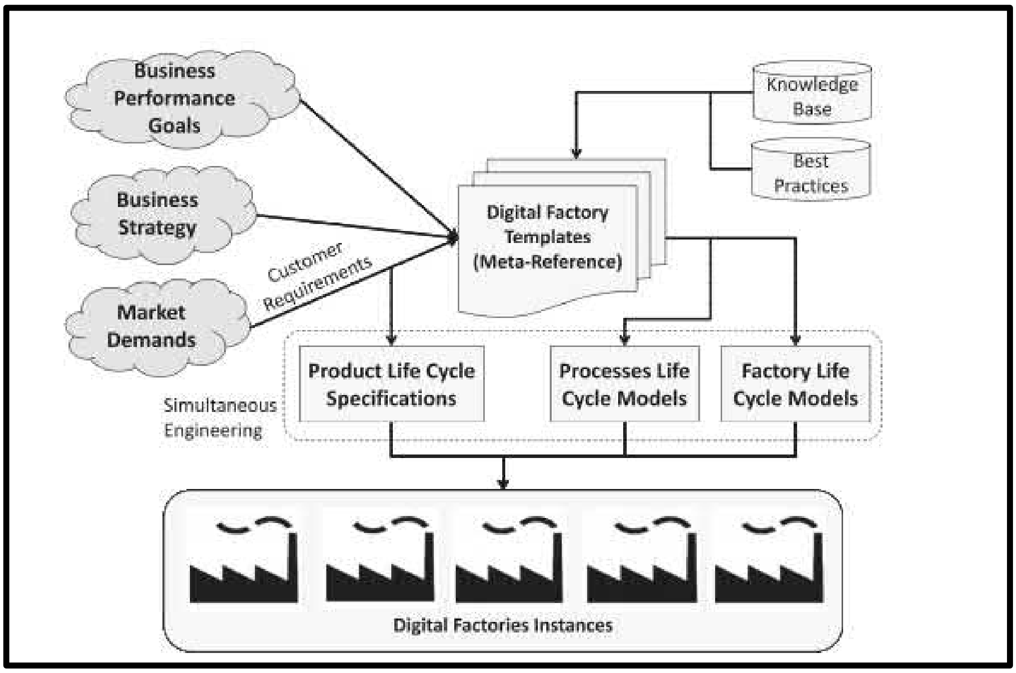

Figure 8: A typical template for the TC to integrate with technology[18]

An Implementation plan for adoption by TC and the impact are shown in Table 6.

[18] Factory Templates for Digital Factories Framework. Azevedo Ame´ ricon, Almeida Anto´nio

Impact Diagram													
Activity	**Outcome**	**T+3 months**	**T+6 months**	**T+9 months**	**T+12 months**	**T+15 months**	**T+18 months**	**T+21 months**	**T+24 months**	**T+27 months**	**T+30 months**	**T+33 months**	**T+36 months**
Reorganizing a model cell within TC and implement TCs own production with the newer trend	Model cell for use of TC and demonstrations to MSMEs	Orient staff to newer methods											
		Details of Model											
			Procurement of Hardware/Software										
				Install and trial run model cell									
Demonstrate the operation of Model cell to the MSMEs:	MSMEs convinced on benefits of newer techniques	Identify and quantify operational benefits to MSMEs											
					Train MSMEs in model cell								
Prepare the training modules for the following	Formal documents for technology transfer to MSMEs ready	Prepare the syllabus for the training program											
					Offer regular training to fresh entrants and existing operatives of cluster								
Run Workshops and training programs:	Regular courses for newer methods on offer to MSMEs and new entrants		Train TC staff on newer batch production techniques										
				Regular training programs for industry									
				Full courses for new entrants									

Table 6: Implementation Roadmap

9. Way forward

The production systems and processes shall be flexible so that it can meet with the trends of increasing complexity of products and supply-chains related to engineering products. Batch production methodology is most suited for this purpose. To ensure that the best aspects of mass and automated production are available to batch production, the MSMEs shall use the various newer technologies and processes described above in the study. Newer technologies are currently revolutionizing batch production manufacturing methodology around the globe and is catching up in India as well – in the engineering industry. This will help Indian engineering and associated sectors like auto, aviation, and precision parts manufacturing to keep pace with the global markets. TC has a major role in demonstrating and supporting the use of technologies by the MSMEs. The next steps to be taken in this direction are listed below:

Capacity building within TC and the cluster:

TCs can initiate capacity building of its staff and MSMEs on these newer technologies. This will help to bridge the gap in understanding the benefits, relevance and to fill the voids of technical know-how and suggest a customized action plan for implementation.

Setting up a Model cell:

As a way forward TCs can initiate to adopt these technologies at the pilot level by forming a model cell. The model cell will be made with the existing machines and that too at their existing location in the shop floor. These machines are decided based on the operations covered like milling; grinding followed by the inspection on CMM. More machines can be added in the future. The above implementation plan can help TC in implementing emerging technologies and increase connectivity, visualization with integration for initiating in becoming a smart factory. The objective of the Model cell is to showcase the utility of Industry 4.0 to the manufacturing industry in general and immediately to the Aurangabad cluster.

Training the MSMEs and new entrants to the industry:

TCs can initiate capacity building of MSMEs and students / new entrants to the industry on these emerging technologies as these skills will play a key role in the employment and knowledge on these technologies will enhance employability.

Strengthening the consultancy in newer methods in batch production:

MSMEs can start with low-cost small initiatives as implementation is customizable as per existing systems of enterprises. The myth that these are very high-end technologies can be dispelled by TCs as it would create awareness amongst MSMEs of the cluster.

The implementation of the newer technologies will benefit TCs also to enhance its production output. This benefit and experience will be transferred to the MSMEs in the TC associated engineering clusters.

For further information, please connect with:

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