International Journal of Research In Science & Engineering e-ISSN: 2394-8299
Volume: 3 Issue: 2 March-April 2017 p-ISSN: 2394-8280

REVERSE ENGINEERING ON PROCESS CYCLE TIME IN A MEDIUM SCALE INDUSTRY

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ABSTRACT

Reverse engineering (Back Engineering) is the process of extracting knowledge or design information from anything man-made and re-producing it or re-producing anything based on the extracted information. There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. This is a paper for people interested in Reverse Engineering (RE) from an industrial perspective. Several journal papers have discussed issues related to RE, but there is a huge gap in practical literature in this field, especially in manufacturing. We are implementing RE on process cycle time in a Medium Scale Industry to cross-check whether the existing process cycle time is minimal or not and to give suggestion on the same if we find the answer as "NO" for the above question.

Keywords*:*
Reverse Engineering, Forward Engineering, Manufacturing, Total Process Cycle Tim, Medium Scale Industry

1. MANUFACTURING

Manufacturing is part of a bigger scheme known as operations. The term Operations takes in all systems that involve getting work done. This includes services as well as manufacture. The process always involves a transformation of some raw materials (or inputs) to a finished item or service. The goal is to create and add value to the inputs during the transformation. In the case of manufacturing, the goal is to add value to a raw material by changing its shape or properties. In the case of a service, often knowledge or know how is brought together to fulfill some need. The process is shown in the diagram below (Fig. 1).

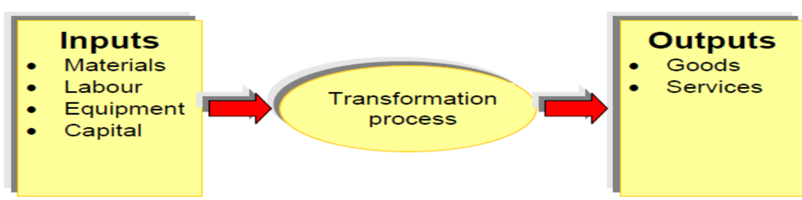

Fig. 1: Manufacturing Process

1.1. Types of Production Processes

The choice of the processes used to make an item depends on the characteristics of the product and the volume of the product being made. Production processes can be classified into projects, batch production, mass production and continuous production (Fig. 2). These are outlined below.

1) ***A Project*** takes a long time to complete, involves a large investment of resources and produces one item at a time to a customer order. Examples include
   - roads,

- construction projects,
- aircraft manufacturing
- new product development e.g. iPhone where the outcome of the project is a prototype iPhone.

2) ***Batch Production*** involves moving groups of the product through the manufacturing process in groups or batches. The volume is relatively low and demand for the items can fluctuate. Examples of batch production are
   - bakeries,
   - furniture making
   - cheese making etc
3) ***Mass Production*** produces large volumes of a standard product for a mass market. The demand for the product is stable and the demand is high. Most consumer goods are produced using this method. Examples are
   - cars,
   - computers
   - fast food such as burgers

   There is usually a degree of automation involved.
4) ***Continuous Production*** is used for very high volume products. These are highly standardised and are produced using highly automated systems. Examples of this are
   - electricity,
   - treated water,
   - foodstuffs,
   - paper

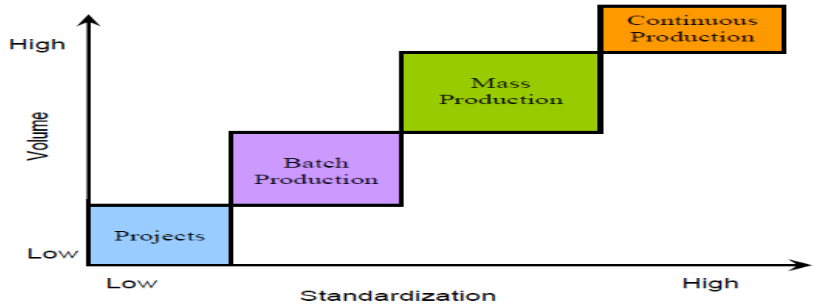

Fig. 2: Production Processes

2. MANUFACTURING LAYOUT

In industry sectors, it is important to manufacture the products which have good quality and meet customers' demand. This action could be conducted under existing resources such as employees, machines and other facilities. However, plant layout improvement, could be one of the tools to response to increasing industrial productivity. Plant layout design has become a fundamental basis of today's industrial plants which can influence parts of work efficiency. It is needed to appropriately plan and position employees, materials, machines, equipment, and other manufacturing supports and facilities to create the most effective plant layout.

The ability to design and operate manufacturing facilities that can quickly and effectively adapt to changing technological and market requirements is becoming increasingly important to the success of any manufacturing organization. In the face of shorter product life cycles, higher product variety, increasingly unpredictable demand, and shorter delivery times, manufacturing facilities dedicated to a single product line cannot be cost effective any longer. Investment efficiency now requires that manufacturing facilities be able to shift quickly from one product line to another without major retooling, resource reconfiguration, or replacement of equipment.

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2.1. Manufacturing Layout Parameters

1) ***Process time****:* The period during which one or more inputs are transformed into a finished product by a manufacturing procedure. A business will typically seek to minimize its process time for a particular manufactured good without compromising quality to the point where consumers would purchase less of it.
2) ***Work in process****:* It is the sum of all costs put into the production process to manufacture products that are partially completed. WIP refers to raw materials, labor and overhead costs incurred for products that are at various stages of the production process. WIP is a component of the inventory asset account on the balance sheet, and these costs are transferred to the finished goods account and eventually to cost of sales.

3. MANUFACTURING SYSTEMS

We define a manufacturing system is a collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts. The integrated equipment includes production machines and tools, material handling and work positioning devices, and computer systems. Human resources are required either full time or periodically to keep the system running. The manufacturing system is where the value-added work is accomplished on the part or product.

Companies rely on a variety of manufacturing systems to produce everything from consumer goods to high-tech electronics. Whether you're starting a new business or taking a critical look at your existing firm, understanding different types of manufacturing systems is critical to success. The right manufacturing system can help your firm meet production goals, maintain high quality standards and keep costs low and profits high.

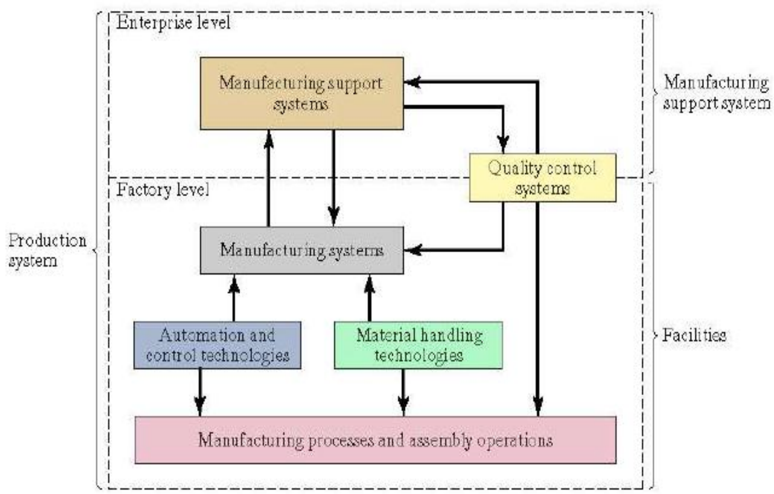

Fig. 3: Manufacturing Systems in Production System

Definition of manufacturing System:
"*A collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts.*"

The various equipments that comprise a Manufacturing System are:
- Production machines and tools
- Material handling and work positioning devices
- Computer systems
- Human resources are required either full-time or periodically to keep the system running

A Manufacturing System is where the value added work is accomplished on the parts and the products.

3.1. Types of Manufacturing Systems

1) Custom Manufacturing System

Custom manufacturing systems represent one of the oldest and most widely used forms of product making. In this system, a single craftsman produces one item at a time by hand or by machine. If machines are used in this system, they are often highly specialized, and capable of producing only a single line of merchandise. This system offers the lowest level of efficiency and highest cost per unit, and results in very low levels of production.

2) Intermittent Manufacturing System

Intermittent manufacturing systems, often called "job shops," are capable of producing multiple items at the same time. These objects must be identical, or very similar, and cannot be customized for individual buyers. This type of system works best for limited production runs, or for companies looking to produce a low volume of goods.

3) Continuous Manufacturing System

Continuous manufacturing systems allow for mass production of products. In this system, the product moves from station to station along an assembly line, with different workers performing various production tasks along the way. Continuous systems were first used during the Industrial Revolution, and are often associated with the Ford Company's Model T production. This type of system allows companies to meet high production goals, and results in a lower per-unit cost. Because of the large amount of equipment required to create an assembly line, as well as the level of labor, this type of system is often associated with large capital investments.

4) Flexible Manufacturing System

Flexible manufacturing systems represent one of the most widely used modern production systems. In this type of setup, companies invest in a variety of machinery that can be quickly and easily reconfigured to produce a large number of products. Flexible manufacturing often incorporates robots or automatic vehicles to help move products through the production process, eliminating the need for skilled labor.

This type of system allows for a high degree of flexibility in terms of product mix, and helps the company maintain high volume in each production run. Because robots replace human labor in this type of system, products tend to be fairly consistent and quality remains high. This system requires a high degree of capital investment as well as frequent maintenance and oversight.

3.2. Manufacturing System Functions

1) ***Total Process Cycle time****:* Cycle time is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action.

Cycle Time = Service Time + Idle Time

IJRISE International Journal of Research In Science & Engineering e-ISSN: 2394-8299
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The cycle time depends on the total output required and the available time for production.

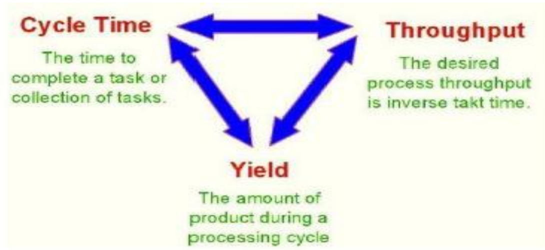

Fig. 4: Cycle Time

Suppose
T = Useful production time available per day and Q = Daily output required in number of units.
Then C = T / Q

2) ***Throughput time***:
The time that a part spends in the system from the moment it is released from the inventory to the time it leaves the system.

3.3. Factors affecting Manufacturing Cycle Time

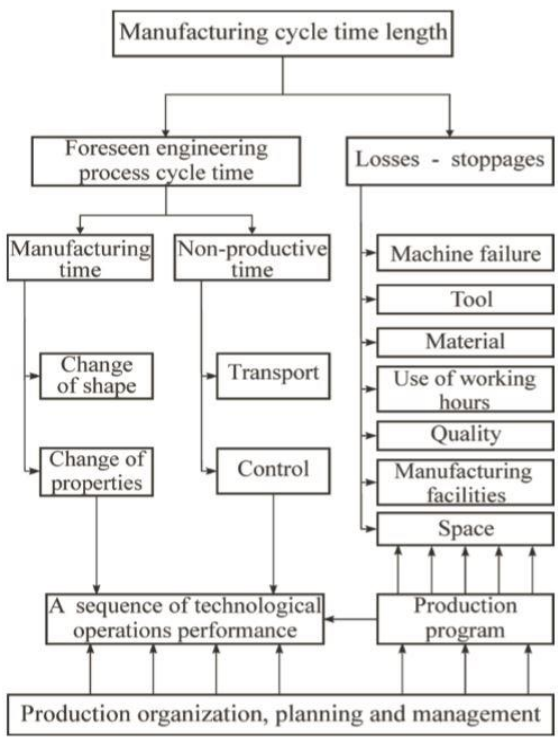

Fig. 5: Several factors on manufacturing cycle time duration (Jovanovic J. R. et al. (2014)) [3]

3.4. Advantages of Reduced Cycle Time

1) More responsive to changing customer demands.
2) Quicker time to market with new products.
3) Save money by reducing WIP (Work in progress)
4) Increase yield
5) Quicker feedback for the process development and process capability improvement programs.
6) Additional savings through incremental improvements:
    - Improved employee productivity, which means savings if fewer employees are needed or increased factory output if consistent with factory goals.
    - Improved equipment utilization by being smarter about maintenance, set ups, production tests, balance, etc.
    - Reduced non productive tests and process control measurements.

3.5. Methods to Improve Cycle Time

There are several efforts suitable for reducing cycle times. Streamlining multiple efforts, however, can yield a much more efficient process resulting in cost and time savings and customer satisfaction. When reducing process cycle time, consider a combination of the following ideas.

1) ***Perform activities in parallel**:*

   Most of the steps in a business process are often performed in sequence. A serial approach results in the cycle time for the entire process being the sum of the individual steps, not to mention transport and waiting time between steps. When using a parallel approach, the cycle time can be reduced by as much as 80% and produces a better result.

   A classic example is product development, where the current trend is toward concurrent engineering. Instead of forming a concept, making drawings, creating a bill of materials, and mapping processes, all activities take place in parallel by integrated teams. In doing so, the development time is reduced dramatically, and the needs of all those involved are addressed during the development process.

2) ***Change the sequence of activities:***

   Documents and products are often transported back and forth between machines, departments, buildings, and so forth. For instance, a document might be transferred between two offices a number of times for inspection and signing. If the sequence of some of these activities can be altered, it may be possible to perform much of the document's processing when it comes to a building the first time.

3) ***Reduce interruptions**:*

   Any issue that causes long delays and increases the cycle time for a critical business process is an interruption. The production of an important order can, for example, be stopped by an order from a far less valuable customer request--one that must be rushed because it has been delayed. Similarly, anyone working amidst a critical business process can be interrupted by a phone call that could have been handled by someone else. The main principle is that everything should be done to allow uninterrupted operation of the critical business processes and let others handle interruptions.

4) ***Improve timing**:*

   Many processes are performed with relatively large time intervals between each activity. For example, a purchasing order may only be issued every other day. Individuals using such reports should be aware of deadlines to avoid missing them, as improved timing in these processes can save many days of cycle time.

4. CYCLE TIME REDUCTION

Cycle time reduction is one of the most important elements of successful manufacturing today. More and more customers are demanding that manufacturers quickly respond to their wants and needs, deliver perfect quality products on time. This trend, which will continue, has led companies to focus more attention on their order-to-delivery cycle time.

Order-to-delivery cycle time reduction is often a good place to start in the overall effort to improve operations because it can often be done without heavy capital investment. Clearly, long cycle times cause high inventories, higher cost, and poor customer service. As a result, many manufacturers are streamlining internal and external supply operations to reduce overall order-to-cash cycle time. Some have even undertaken initiatives to extensively redesign and streamline the entire supply chain process.

A major consequence of this trend is that top management are revisiting their existing strategies and operational tactics. That in turn has led many to pursue new initiatives and directions, including:

- **Demand Management -** Using improved sales forecasting processes and sales and operations planning processes to give top management a better handle on demand and supply.
- **Cross-functional Integration -** Redesigning order-to-delivery process and other key processes to connect all processes across the factory.
- **Lean Manufacturing -** Radically redesigning information flow and material flow processes with dramatically shorter cycle times, lower costs, minimum inventory, and near perfect delivery performance.
- **Supply Chain Management -** Implementing supply chain planning, execution, and event-level alert systems, sometimes in conjunction with other modern information technology. As customers up the ante by insisting orders be promptly delivered and at a precise time, reducing cycle time becomes the pivotal point in a supplier order-to delivery performance rating. A shorter order-to-delivery cycle time also has other implications, including reduced inventories, lower costs, and more effective use of resources.

In addition, experience has shown that production throughput can improve dramatically once the order-to-delivery cycle time is substantially reduced. An added set of benefits affects the bottom line in lower operating expenses, dramatically decreased requirements for working capital, and increased profit margins.

5. LITERATURE REVIEW

Arvind R. and Gunasekaran N. (2014) [1]. Cycle time should be considered as a viable option when an organization is trying to improve efficiency, cost base and customer responsive. Value stream mapping is a paper and pencil tool that helps you to see and understand the flow of material and information as a product or service makes its way through the value stream. This paper proposes how this valuable tool can be implemented effectively in means of loading and unloading of the materials. Forming a current state map for eliminating the
non-value added activities, also to derive a future state map for reducing the cycle time and improve the process efficiency.

Jangale Y. G. and Deshmukh R.R., (2015) [2]. In small scale industry the current environment tends to force employee to work in isolation also it observed that they works on conventional machines when CNC or VMC machines are available, this is because of some certain problems which are not analyzed properly or failure to find root cause by system. To eliminate this mentality of workers there should be close neat observation of supervisory control is essential, also it is necessary to built an error proof system which lead to develop a system which focuses on productivity & quality control. This paper deals with design of low budget system for CAD-CAM-CAPP integration for a small scale die manufacturing industry to reduce lead time during production.

To measure the effect of manufacturing capacity utilization levels and causes of losses, and to optimize the flow coefficients, and so to reduce manufacturing cycle time **Jovanovic J. R. et al. (2014) [3]** described an original approach for the scheduling of production cycles on the basics of theoretical investigation of the manufacturing documentation of special-purpose products by taking into account the serial production characterized by discontinuity and current assets needed for financing the production process. A theoretical analysis has been carried out to establish the technological and real manufacturing cycle time, total loses and flow coefficient (Kp and Kt). It has been suggested that the flow coefficient K_t should be prioritize to get the comparable results from the presented model with other business-manufacturing systems.

Patel N. (2015) [4]. Applied the Time study method carried out the experimental work to optimal levels of time and defect rate reductions along with the corresponding optimal levels of investments respectively, and the optimal production cycle time by time study method.

Raja Vinesh. This chapter introduces readers to the term reverse engineering (RE), and to the associated techniques that can be used for scanning physical parts. In addition, the chapter presents the process of reverse engineering and the strategy for scanning and converting the scanned data into a 3-D surface or solid model.

Saraswatp et al. (2015) In this paper Value Stream Mapping (VSM) tool is used in bearing manufacturing industry by focusing both on processes and their cycle times for a product UC- 208 INNER which is used in plumber block. In order to use the value stream mapping, relevant data has been collected and analyzed. After collecting the data customer need was identified. Current state map was draw by defining the resources and activities needed to manufacture, deliver the product. The study of current state map shows the areas for improvement and identifying the different types of wastes. From the current state map, it was noticeable that Annealing and CNC Machining processing have higher cycle time and work in process.

Singh Niranjan et. al (2012) The process of duplicating an existing part, subassembly, or product without the aid of drawings, documentation, or a computer model is known as reverse engineering. Reverse engineering is also defined as the process of obtaining a geometric CAD model from 3D points acquired by scanning/ digitizing the existing products. The aim of this paper is to review the reverse engineering process, and its role in the development, refinement and modifications in the existing design of product has been discussed. After a brief introduction, the various stages involved in reverse engineering, and its applications in different fields have been discussed. A brief historical events using reverse engineering technique have also been discussed at length.

Toprakwar Manish D. et. al. (2015). This research paper presents the application of reverse engineering in medical field. Over last 15 years the production of preoperative planning model has increased dramatically and moreover. The use of this model will helpful for surgeon to reduce risk, time of operation and increase the patient confidence and life also. The first step in reverse engineering is CT scanning and digitization of data. The CT data obtained in DICOM format which is subjected to processing and imported in CAD program for further customization and STL formation . So in such cases it is necessary to evaluate the model whether it is manufactured accurately or not. As human body has irregular structure, so it is not possible to model & manufacture accurately such a critical shape like human bone, craniofacial implants etc. On completion of this paper it became apparent that certain RP technologies and associated software such as Mimics and 3-matic has indeed many advantages to offer the medical profession with regard to preoperative planning models and customized medical implants. Although not fully accepted by all, constant research and development in RP technology, biomaterials and software solutions, means that medical implant technology will continue to improve. In this paper the result of dimensional & error analysis of Humerus customized implant manufactured by RP (FDM) has been discussed by using advance optical measurement technique.

Wang Wego. This paper discusses the practice of reverse engineering that usually consists of two phases: (1) decoding the original design details with programmatic analysis, and (2) reproducing an “identical” counterpart. The most challenging technical tasks in both phases are directly related to manufacturing processes because the prior history or trails of many manufacturing processes are erased in the final product. Following a broad discussion on potential applications of reverse engineering and their potential benefits, this paper will focus on the technical challenges of applying reverse engineering in verifying and reinventing the part manufacturing process.

6. CONCLUSION

The two primary objectives of applying Reverse Engineering (RE) in manufacturing are to reinvent a part for market competition or for part restoration. Technically both these objectives heavily rely on the success of three key elements: material composition identification, part dimension determination, and manufacturing process time. As the manufacturing process time plays a vital role in product cost. For minimizing the product cost, we have to minimize the overall process cycle time of a product. There are several methods to optimize the overall process cycle time and successfully implemented in an industry. By applying RE on process cycle time, we are step forwarding in the direction of applications of RE in manufacturing field.

There is also an increased demand across all application domains surveyed for cost-effective techniques able to reduce the total cost of development, operation, and maintenance of complex technical solutions. This demand triggers the need for increasingly accurate and detailed information of the structure, dynamics, and semantics of processes and artifacts involved in such solutions. Reverse engineering plays a vital role in providing such accurate and detailed information for resolving complex issues/problems. Effective use of reverse engineering application, especially in the field of manufacturing, is expected to penetrate market in the future.

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