

<b>COURSE CODE:</b>	<i>MCE 510</i>
<b>COURSE TITLE:</b>	<i>Industrial Engineering</i>
<b>NUMBER OF UNITS:</b>	<i>3 Units</i>
<b>COURSE DURATION:</b>	<i>Three hours per week</i>

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### **COURSE DETAILS:**

<b>Course Coordinator:</b>	<b>Engr. Prof. Sam. B. ADEJUYIGBE</b>
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<b>Office Location:</b>	<b>Dean's Office, COLENG</b>
<b>Other Lecturers:</b>	<b>None</b>

### **COURSE CONTENT:**

Introduction, system engineering applied to the design of industrial business system and organization. Industrial organization. Operation subsystem design, production planning and control, purchasing. Operation subsystem design, production planning and control, purchasing. Motion and time study. Factory planning and material handling. Industrial Standardization. Tool and manufacturing engineering. Industrial statistics. Inspection and quality control. The attitudes of organized labour towards industrial engineering methods.

### **COURSE REQUIREMENTS:**

This is an elective course for all 500 level students of Mechanical Engineering. In view of this, students who selected this course are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

### **READING LIST:**

1. **Adejuyigbe, S. B. (1997)** Metal Cutting Machine Tools. Engineering Textbook. Publication for Universities, Polytechnics, Colleges of Education, Technical Colleges and Secondary Schools. Olajuyin Printers and TopFun Publications, Akure – 220 pages. ISBN 978-32744-3-0
2. **ADEJUYIGBE, S. B. (1998)** Professional Engineering Practice. Engineering Textbook. Publication for Universities, Polytechnics, Colleges of Education, Technical Colleges and Secondary Schools. TopFun Publications, Akure – 69 pages. ISBN 978-028-378-1.
3. **ADEJUYIGBE, S. B. (1998)** Engineering Law and Management. Engineering Textbook. Publication for Universities, Polytechnics, Colleges of Education, Technical Colleges and Secondary Schools. TopFun Publications, Akure – 70 pages. ISBN 978-028-377-3.
4. **Adejuyigbe, S. B. (2000)** Tools Design for Metal Cutting. Engineering Textbook. Publication for Universities, Polytechnics, Colleges of Education, Technical Colleges and Secondary Schools. Publications, Akure – 220 pages. ISBN 978-34859-2-X.

5. **Adejuyigbe, S. B. (2002)** Production Management (Design, Planning, Control and Implementation). Engineering Textbook. Publication for Universities, Polytechnics, Business Schools and Technical Colleges. TopFun Publications, Akure – 150 pages, A4 size. ISBN 978-34859-1-1.
6. **Adejuyigbe, S.B. (2007)** Applied Manufacturing Engineering Processes. Engineering Textbook Publications for Universities, Polytechnics, Business and Technical Colleges. TopFun Publications, Akure – 325 pages, A4 size. ISBN 978-34659-8-9.
7. **Cross, N. (1989)** Engineering Design Methods, Chichester: Wiley.
8. **Gilbreth, Frank B. (1910)** *Motion Study: A Method for Increasing the Efficiency of the Workman*, D. Van Nostrand, New York, NY. Available at:
9. **Groover, Mikell P. (2007)** *Work Systems and Methods, Measurement, and Management of Work*, Pearson Education International
10. **Godfrey, A. B., Juran's Quality Handbook**, 1999. ISBN 007034003
11. **IIE, ANSI (1982)**. Industrial Engineering Terminology, Standard Z94.1-12.
12. **Pigage, L. and Tucker, J. (1954)**, Motion and time study, Institute of Labor and Industrial Relations Bulletin, University of Illinois, Illinois, Vol. 6, No. 24. Available at: <http://hdl.handle.net/2142/9385>
13. **Pyzdek, T., Quality Engineering Handbook**, 2003. ISBN 0824746147.
14. **Robbins, S.P., Bergman, R., Stagg, L. and Coulter, M. (2003)**, *Management*, 3rd edition, Prentice, Sydney, Australia.
15. **Rozenburg, N.F.M. and Eekels, J. (1995)** Product Design: Fundamentals and Methods, Utrecht: Lemma.
16. **Salvendy, G. (Ed.) (2001)** *Handbook of Industrial Engineering: Technology and Operations Management*, third edition, John Wiley & Sons, Hoboken, NJ.
17. **Thomas E., Vollmann, William L. Berry, D. Clay Whybark, F. Robert Jacobs; 2005 -** Manufacturing Planning and Control Systems for Supply Chain Management;
18. **Zandin, K. (Ed.) (2001)** *Maynard's Industrial Engineering Handbook*, 5th edition, McGraw-Hill, New York, NY..

## LECTURE NOTES

### Introduction to the Course

This field pertains to the efficient use of machinery, labour, and raw materials in industrial production. It is particularly important from the viewpoint of costs and economics of production, safety of human operators, and the most advantageous deployment of automatic machinery

**Industrial engineering** is the branch of engineering that is concerned with the efficient production of industrial goods as affected by elements such as plant and procedural design, the management of materials and energy, and the integration of workers within the overall system. It is the branch of engineering that deals with the creation and management of systems that integrate people and materials and energy in productive ways

Industrial management applied science, engineering science, technology, engineering - the discipline dealing with the art or science of applying scientific knowledge to practical problems; "he had trouble deciding which branch of engineering to study"

It is also defined as a branch of engineering dealing with the optimization of complex processes or systems. It is concerned with the development, improvement, implementation and evaluation of integrated systems of people, money, knowledge, information, equipment, energy, materials, analysis and synthesis, as well as the mathematical, physical and social

sciences together with the principles and methods of engineering design to specify, predict, and evaluate the results to be obtained from such systems or processes. Its underlying concepts overlap considerably with certain business-oriented disciplines such as operations management, but the engineering side tends to emphasize extensive *mathematical* proficiency and usage of quantitative methods.

Depending on the sub-specialties involved, industrial engineering may also be known as operations management, management science, operations research, systems engineering, or manufacturing engineering, usually depending on the viewpoint or motives of the user. Recruiters or educational establishments use the names to differentiate themselves from others. In health care, industrial engineers are more commonly known as health management engineers or health systems engineers.

**According to IIE official definition Industrial engineering** is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.

**Industrial engineers** determine the most effective ways to use the basic factors of production -- people, machines, materials, information, and energy -- to make a product or to provide a service. They are the bridge between management goals and operational performance. They are more concerned with increasing productivity through the management of people, methods of business organization, and technology than are engineers in other specialties, who generally work more with products or processes. Although most industrial engineers work in manufacturing industries, they may also work in consulting services, healthcare, and communications.

To solve organizational, production, and related problems most efficiently, industrial engineers carefully study the product and its requirements, use mathematical methods such as operations research to meet those requirements, and design manufacturing and information systems. They develop management control systems to aid in financial planning and cost analysis and design production planning and control systems to coordinate activities and ensure product quality. They also design or improve systems for the physical distribution of goods and services. Industrial engineers determine which plant location has the best combination of raw materials availability, transportation facilities, and costs. Industrial engineers use computers for simulations and to control various activities and devices, such as assembly lines and robots.

They also develop wage and salary administration systems and job evaluation programs.

Many industrial engineers move into management positions because the work is closely related. The work of health and safety engineers is similar to that of industrial engineers in that it deals with the entire production process. Health and safety engineers promote worksite or product safety and health by applying knowledge of industrial processes, as well as mechanical, chemical, and psychological principles. They must be able to anticipate, recognize, and evaluate hazardous conditions as well as develop hazard control methods. They also must be familiar with the application of health and safety regulations.

### **Teams and Coworkers**

Almost all jobs in engineering require some sort of interaction with coworkers. Whether they are working in a team situation, or just asking for advice, most engineers have to have the ability to communicate and work with other people. Engineers should be creative, inquisitive, analytical, and detail-oriented. They should be able to work as part of a team and to

communicate well, both orally and in writing. Communication abilities are important because engineers often interact with specialists in a wide range of fields outside engineering.

### **Tasks**

Industrial engineers determine the most effective ways to use the basic factors of production -- people, machines, materials, information, and energy -- to make a product or to provide a service. They are the bridge between management goals and operational performance. They are more concerned with increasing productivity through the management of people, methods of business organization, and technology than are engineers in other specialties, who generally work more with products or processes. Although most industrial engineers work in manufacturing industries, they may also work in consulting services, healthcare, and communications.

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### **Career Path Forecast**

According to the U.S. Department of Labor, Bureau of Labor Statistics, industrial engineers are expected to have employment growth of 20 percent over the projections decade, faster than the average for all occupations. As firms look for new ways to reduce costs and raise productivity, they increasingly will turn to industrial engineers to develop more efficient processes and reduce costs, delays, and waste.

This should lead to job growth for these engineers, even in manufacturing industries with slowly growing or declining employment overall. Because their work is similar to that done in management occupations, many industrial engineers leave the occupation to become managers. Many openings will be created by the need to replace industrial engineers who transfer to other occupations or leave the labor force.

### **Professional Organizations**

Professional organizations and associations provide a wide range of resources for planning and navigating a career in Nuclear Engineering. These groups can play a key role in your development and keep you abreast of what is happening in your industry. Associations promote the interests of their members and provide a network of contacts that can help you find jobs and move your career forward. They can offer a variety of services including job referral services, continuing education courses, insurance, travel benefits, periodicals, and meeting and conference opportunities. The following is a description of the Institute of Industrial Engineers.

### **Institute of Industrial Engineers (IIE)([www.iienet.org](http://www.iienet.org))**

IIE is the world's largest professional society dedicated solely to the support of the industrial engineering profession and individuals involved with improving quality and productivity.

Founded in 1948, IIE is an international, non-profit association that provides leadership for the application, education, training, research, and development of industrial engineering. With more than 15,000 members and 280 chapters worldwide, IIE's primary mission is to meet the ever-changing needs of its membership, which includes undergraduate and graduate students, engineering practitioners and consultants in all industries, engineering managers, and engineers in education, research, and government.

IIE is recognized internationally as:

- The leading provider of cutting-edge continuing education in industrial engineering.
- The acknowledged source of productivity improvement information via the Internet, publications, and live events, including an annual conference, topical conferences, and technical seminars.
- An invaluable source of member benefits that include a magazine, professional development programs, an online career center, networking communities, chapters, and affinity programs that save members time and money.
- The only association that supports the profession of industrial engineering and promotes an increased awareness of the value of industrial engineers.
- The only association that supports accredited industrial engineering programs through the ABET Inc.

***World leadership-whether for nations, states or individual companies-depends upon providing the highest quality in goods and services at costs that are affordable to the widest possible audience. Retaining world-class status requires relentless continuous improvement in all aspects of the business or governmental enterprise. Industrial engineers use a systems approach and focus on the processes for achieving quality, continuous improvement and cost effectiveness for all types of enterprises-manufacturers, healthcare service industries, non-profits and governments.***

### **The Profession**

Industrial engineers are involved in the creation of wealth and prosperity. This is achieved through designing and implementing better, more productive systems in both a manufacturing and a service environment. Industrial engineering is an interdisciplinary program by nature. Industrial engineers design, install, fabricate and integrate systems that include people, materials, information, equipment and energy necessary to accomplish the desired function. The main areas of employment are in manufacturing, service, consulting and healthcare.

Industrial engineers often are responsible for productivity improvements, supply chain optimization, project management, feasibility studies for new technologies and applications, lean and just-in-time implementation, health care management and logistics, and systems integration and engineering. Whether it's shortening a rollercoaster line, streamlining an operating room, managing a worldwide supply chain, manufacturing and designing superior automobiles, or solving logistics problems, industrial engineers are at the forefront.

### **Overview**

While the term originally applied to manufacturing, the use of "industrial" in "industrial engineering" can be somewhat misleading, since it has grown to encompass any methodical or quantitative approach to optimizing how a process, system, or organization operates. Some engineering universities and educational agencies around the world have changed the term "industrial" to the broader term "production", leading to the typical extensions noted above. In fact, the primary U.S. professional organization for Industrial Engineers, the Institute of Industrial Engineers (IIE) has been considering changing its name to something broader (such as the Institute of Industrial & Systems Engineers), although the latest vote among membership deemed this unnecessary for the time being.

The various topics of concern to industrial engineers include management science, financial engineering, engineering management, supply chain management, process engineering, operations research, systems engineering, ergonomics, cost and value engineering, quality engineering, facilities planning, and the engineering design

process. Traditionally, a major aspect of industrial engineering was planning the layouts of factories and designing assembly lines and other manufacturing paradigms. And now, in so-called lean manufacturing systems, industrial engineers work to eliminate wastes of time, money, materials, energy, and other resources.

Examples of where industrial engineering might be used include designing an assembly workstation, strategizing for various operational logistics, consulting as an efficiency expert, developing a new financial algorithm or loan system for a bank, streamlining operation and emergency room location or usage in a hospital, planning complex distribution schemes for materials or products (referred to as Supply Chain Management), and shortening lines (or queues) at a bank, hospital, or a theme park.

Industrial engineers typically use computer simulation (especially discrete event simulation), along with extensive mathematical tools and modeling and computational methods for system analysis, evaluation, and optimization

## **Systems Engineering Applied to Design of Industrial Business Systems and Organization.**

### **System**

There are many definitions of what a system is in the field of systems engineering. Below are a few authoritative definitions:

- ANSI/EIA-632-1999: "An aggregation of end products and enabling products to achieve a given purpose."
- IEEE Std 1220-1998: "A set or arrangement of elements and processes that are related and whose behavior satisfies customer/operational needs and provides for life cycle sustainment of the products."
- ISO/IEC 15288:2008: "A combination of interacting elements organized to achieve one or more stated purposes."<sup>1</sup>
- NASA Systems Engineering Handbook: "(1) The combination of elements that function together to produce the capability to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose. (2) The end product (which performs operational functions) and enabling products (which provide life-cycle support services to the operational end products) that make up a system."
- INCOSE Systems Engineering Handbook: "homogeneous entity that exhibits predefined behavior in the real world and is composed of heterogeneous parts that do not individually exhibit that behavior and an integrated configuration of components and/or subsystems."
- INCOSE: "A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected."<sup>[33]</sup>

## Concept of System Design

We are already experiencing a complex society. So also the industrial set up is passing through complex changes in their day to day operations. As more people are becoming learned, the rules of thumb cannot be highly relied upon. Hence, the development of systems concept.

System concept is a systematic approach to get the task accomplished for efficiently, affectively and economically for industries and large organisations, it also tells how to manage the jobs or how to analyse complex phenomena under different circumstances and environment, it is used to build the model of a system, and solve the business or human values problem.

System engineering is concerned with information systems or non-physical systems whereas industrial engineering is concerned with both physical and non-physical systems.

A system is the collection of interacting elements that operates to achieve a pre-determined objective. It optimizes some function of input and output. Examples of a system are:

- A human body is a system that has various sub-systems like, blood circulation, nervous system, eating capability etc.
- Industry can also be termed to be a system that has various sub-systems like production, sales, inventory. Etc.
- Transportation is another system that has a subsystem like rail, road, and marine transportation

A system is termed to be dynamic in nature, which can come as animate (school building and all students) or inanimate (thunder storm).

In animate system example of the input is teaching, chalk, students, etc. the process unit includes lectures/or teachers, other staff and laboratories and equipment. The output is the graduates and the objective is to teach the students satisfactorily as many as possible in a given time.

## Classification of system

A system may be classified into 3 major types thus;

- i. Mechanistic: is one that is fully mechanised although the choice of system composition remains in the hands of human beings, example are dial telephone, space rockets etc.
- ii. Quasi-Mechanistic: this is the process where human beings carry out some of the mechanical functions, example is a fighter plane.
- iii. Non-Mechanistic: it is possible that human elements act or take decisions and improve the system. Example is the production system.

## System Analysis

In the system analysis you need to:

- i. Study the system; and
- ii. Construct the system.  
The procedure involves
  - i. Define the objective;
  - ii. Providing alternative-which can achieve the objective;
  - iii. Model building – physical or mathematical
  - iv. Criterion – evaluation of the interior specified
  - v. Preference – wise alternatives – choose out of the various alternatives available
  - vi. Verification – test your alternatives by experiments

## System Engineering

It involves the analysis and synthesis of systems. It involve three major steps for designing complex and highly engineering equipment system thus;

- i. Define the problem – input and output and the requirement of the system must be specified
- ii. Solve the problem – identify the system, sub-system, sub-system interface and check the performance of the system.
- iii. Check the solution – this is to ascertain that the designed equipment system functions very well and fulfill its requirements

### Techniques in system analysis

The technique used for solving problem in the system analysis depend on the mathematical equation arrived at when solving the problem. Some of the techniques are;

- i. Operation Research
- ii. Program Evaluation and Review Technique (PERT);
- iii. Critical Path Method (CPM); and
- iv. Simulation
- v. System analysis has different scope from that of operations research in the conventional sense. It is a discipline with logic of its own; Similar in many respects to that of operations research, but also different in some fundamental aspects.
- vi. The production/industrial engineering fields has grown considerably in the direction of system analysis.

A system may present a negative feedback as shown in the fig. 1 below

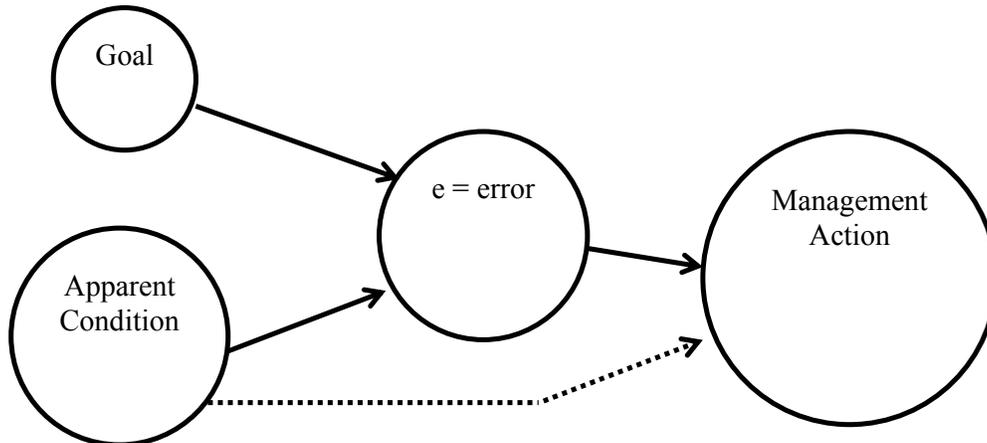


Fig 1: Negative feedback in management system

### System reliability

System, even including managerial systems, can be considered to be two types thus;

- a) Series system: where there are two or more components operating in series.



Fig 2: A series system

It has the following characteristics:

- i. If either of the two component fails, it is automatic that the system will fail;

- ii. Therefore, the effective reliability of the system between A and B therefore is  
 $C_{AB} = C_1 C_2$  Eqn 1  
 Where  $C_1$  and  $C_2$  denotes the reliability of the two components or the system  
 $C_{TOTAL} = C_1 C_2 \dots \dots \dots C_N$  Eqn 2
- b) Parallel Systems- where two or more components operate in parallel

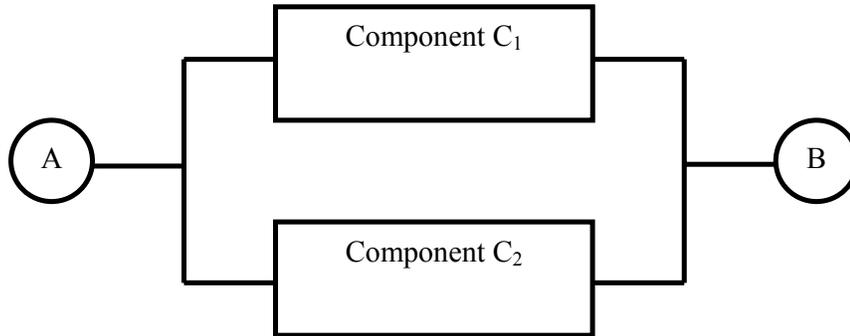


Fig 3: A parallel system  
 It has the following characteristics;

- i. If either of the two components fails, the system will still continue to operate, although performance or efficiency will be reduced.
- ii. Therefore, the effective reliability of the system between A and B is;  
 $C_{AB} = 1 - (1 - C_1) (1 - C_2)$  Eqn 3  
 Or more generally  
 $C_{TOTAL} = 1 - (1 - C_1)(1 - C_2)(1 - C_3) \dots \dots (1 - C_N)$  Eqn 4

From the managerial point of view, the combined reliability of two control systems acting in parallel is greater than that of either system, and it is however noted that the greater the number of systems, the greater the total reliability.

**Systems Engineering**

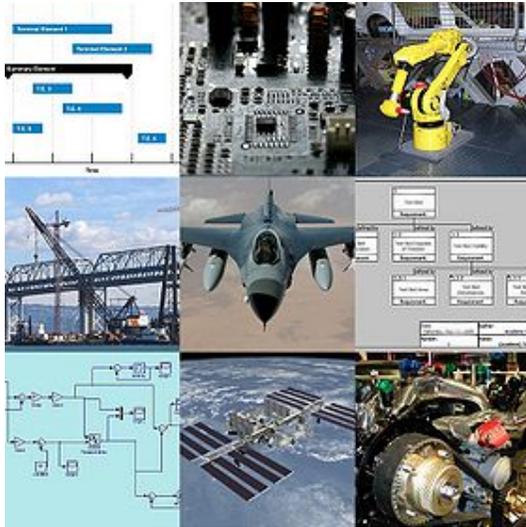
Systems Engineering is an interdisciplinary field of engineering that focuses on how complex engineering projects should be designed and managed over the life cycle of the project. Issues such as logistics, the coordination of different teams, and automatic control of machinery become more difficult when dealing with large, complex projects. Systems engineering deals with work-processes and tools to handle such projects, and it overlaps with both technical and human-centered disciplines such as control engineering, industrial engineering, organizational studies, and project management.

The term *systems engineering* can be traced back to Bell Telephone Laboratories in the 1940s.<sup>[1]</sup> The need to identify and manipulate the properties of a system as a whole, which in complex engineering projects may greatly differ from the sum of the parts' properties, motivated the Department of Defense, NASA, and other industries to apply the discipline.

When it was no longer possible to rely on design evolution to improve upon a system and the existing tools were not sufficient to meet growing demands, new methods began to be developed that addressed the complexity directly.<sup>[3]</sup> The evolution of systems engineering, which continues to this day, comprises the development and identification of new methods and modeling techniques. These methods aid in better comprehension of engineering systems as

they grow more complex. Popular tools that are often used in the systems engineering context were developed during these times, including USL, UML, QFD, and IDEFO.

### Practical Example of Systems Engineering



Systems engineering techniques are used in complex projects: spacecraft design, computer chip design, robotics, software integration, and bridge building. Systems engineering uses a host of tools that include modeling and simulation, requirements analysis and scheduling to manage complexity.

"The systems engineering method recognizes each system is an integrated whole even though composed of diverse, specialized structures and sub-functions. It further recognizes that any system has a number of objectives and that the balance between them may differ widely from system to system. The methods seek to optimize the overall system functions according to the weighted objectives and to achieve maximum compatibility of its parts." — *Systems Engineering Tools* by Harold Chestnut, 1965.

Systems engineering signifies both an approach and, more recently, a discipline in engineering. The aim of education in systems engineering is to simply formalize the approach and in doing so, identify new methods and research opportunities similar to the way it occurs in other fields of engineering. As an approach, systems engineering is holistic and interdisciplinary in flavour.

#### Origins and traditional scope

The traditional scope of engineering embraces the design, development, production and operation of physical systems, and systems engineering, as originally conceived, falls within this scope. "Systems engineering", in this sense of the term, refers to the distinctive set of concepts, methodologies, organizational structures (and so on) that have been developed to meet the challenges of engineering functional physical systems of unprecedented complexity. The Apollo program is a leading example of a systems engineering project.

### **Holistic view**

Systems engineering focuses on analyzing and eliciting customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem, the system lifecycle. Oliver *et al.* claim that the systems engineering process can be decomposed into

- a *Systems Engineering Technical Process*, and
- a *Systems Engineering Management Process*.

Within Oliver's model, the goal of the Management Process is to organize the technical effort in the lifecycle, while the Technical Process includes *assessing available information, defining effectiveness measures, to create a behavior model, create a structure model, perform trade-off analysis, and create sequential build & test plan.*

Depending on their application, although there are several models that are used in the industry, all of them aim to identify the relation between the various stages mentioned above and incorporate feedback. Examples of such models include the Waterfall model and the VEE model

### **Interdisciplinary field**

System development often requires contribution from diverse technical disciplines. By providing a systems (holistic) view of the development effort, systems engineering helps mold all the technical contributors into a unified team effort, forming a structured development process that proceeds from concept to production to operation and, in some cases, to termination and disposal.

### **Managing complexity**

The need for systems engineering arose with the increase in complexity of systems and projects, in turn exponentially increasing the possibility of component friction, and therefore the reliability of the design. When speaking in this context, complexity incorporates not only engineering systems, but also the logical human organization of data. At the same time, a system can become more complex due to an increase in size as well as with an increase in the amount of data, variables, or the number of fields that are involved in the design. The International Space Station is an example of such a system.



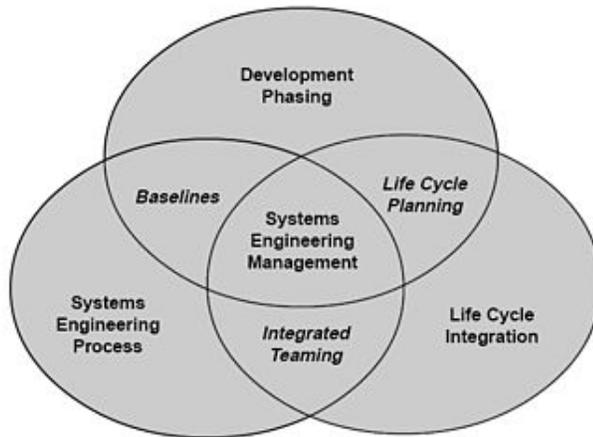
The International Space Station is an example of a largely complex system requiring Systems Engineering.

The development of smarter control algorithms, microprocessor design, and analysis of environmental systems also come within the purview of systems engineering. Systems

engineering encourages the use of tools and methods to better comprehend and manage complexity in systems. Some examples of these tools can be seen here:

Taking an interdisciplinary approach to engineering systems is inherently complex since the behavior of and interaction among system components is not always immediately well defined or understood. Defining and characterizing such systems and subsystems and the interactions among them is one of the goals of systems engineering. In doing so, the gap that exists between informal requirements from users, operators, marketing organizations, and technical specifications is successfully bridged.

### Scope of System Engineering Management



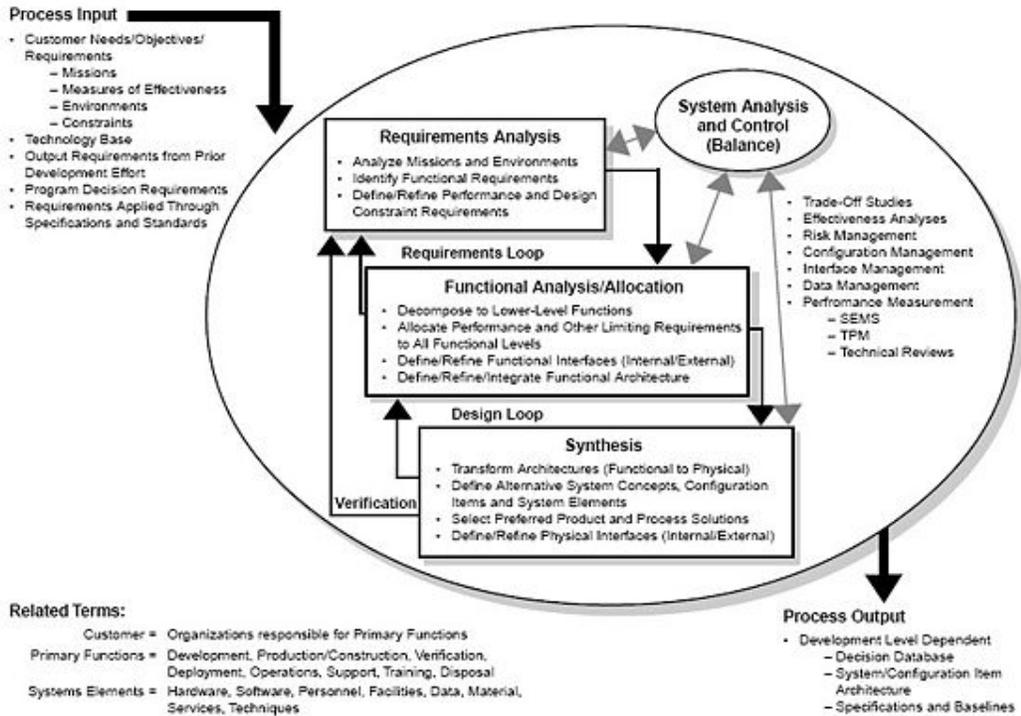
The scope of systems engineering activities

One way to understand the motivation behind systems engineering is to see it as a method, or practice, to identify and improve common rules that exist within a wide variety of systems. Keeping this in mind, the principles of systems engineering — holism, emergent behavior, boundary, et al. — can be applied to any system, complex or otherwise, provided systems thinking is employed at all levels. Besides defense and aerospace, many information and technology based companies, software development firms, and industries in the field of electronics & communications require systems engineers as part of their team.

Systems engineering encourages the use of modeling and simulation to validate assumptions or theories on systems and the interactions within them. Systems engineering tools are strategies, procedures, and techniques that aid in performing systems engineering on a project or product. The purpose of these tools vary from database management, graphical browsing, simulation, and reasoning, to document production, neutral import/export and more.

### The systems engineering process

Depending on their application, tools are used for various stages of the systems engineering process:



### Using models

Models play important and diverse roles in systems engineering. A model can be defined in several ways, including:

- An abstraction of reality designed to answer specific questions about the real world
- An imitation, analogue, or representation of a real world process or structure; or
- A conceptual, mathematical, or physical tool to assist a decision maker.

Together, these definitions are broad enough to encompass physical engineering models used in the verification of a system design, as well as schematic models like a functional flow block diagram and mathematical (i.e., quantitative) models used in the trade study process. This section focuses on the last.<sup>[34]</sup>

The main reason for using mathematical models and diagrams in trade studies is to provide estimates of system effectiveness, performance or technical attributes, and cost from a set of known or estimable quantities. Typically, a collection of separate models is needed to provide all of these outcome variables. The heart of any mathematical model is a set of meaningful quantitative relationships among its inputs and outputs. These relationships can be as simple as adding up constituent quantities to obtain a total, or as complex as a set of differential equations describing the trajectory of a spacecraft in a gravitational field. Ideally, the relationships express causality, not just correlation.

### Tools for graphic representations

Initially, when the primary purpose of a systems engineer is to comprehend a complex problem, graphic representations of a system are used to communicate a system's functional and data requirements.<sup>[35]</sup> Common graphical representations include:

- Functional Flow Block Diagram (FFBD)
- VisSim

- Data Flow Diagram (DFD)
- N2 (N-Squared) Chart
- IDEF0 Diagram
- UML Use case diagram
- UML Sequence diagram
- USL Function Maps and Type Maps.
- Enterprise Architecture frameworks, like TOGAF, MODAF, Zachman Frameworks etc.

A graphical representation relates the various subsystems or parts of a system through functions, data, or interfaces. Any or each of the above methods are used in an industry based on its requirements. For instance, the N2 chart may be used where interfaces between systems is important. Part of the design phase is to create structural and behavioral models of the system.

Once the requirements are understood, it is now the responsibility of a systems engineer to refine them, and to determine, along with other engineers, the best technology for a job. At this point starting with a trade study, systems engineering encourages the use of weighted choices to determine the best option. A decision matrix, or Pugh method, is one way (QFD is another) to make this choice while considering all criteria that are important. The trade study in turn informs the design which again affects the graphic representations of the system (without changing the requirements). In an SE process, this stage represents the iterative step that is carried out until a feasible solution is found. A decision matrix is often populated using techniques such as statistical analysis, reliability analysis, system dynamics (feedback control), and optimization methods.

At times a systems engineer must assess the existence of feasible solutions, and rarely will customer inputs arrive at only one. Some customer requirements will produce no feasible solution. Constraints must be traded to find one or more feasible solutions. The customers' wants become the most valuable input to such a trade and cannot be assumed. Those wants/desires may only be discovered by the customer once the customer finds that he has over constrained the problem. Most commonly, many feasible solutions can be found, and a sufficient set of constraints must be defined to produce an optimal solution. This situation is at times advantageous because one can present an opportunity to improve the design towards one or many ends, such as cost or schedule. Various modeling methods can be used to solve the problem including constraints and a cost function.

Systems Modeling Language (SysML), a modeling language used for systems engineering applications, supports the specification, analysis, design, verification and validation of a broad range of complex systems.

Universal Systems Language (USL) is a systems oriented object modeling language with executable (computer independent) semantics for defining complex systems, including software.

#### **Related fields and sub-fields**

Many related fields may be considered tightly coupled to systems engineering. These areas have contributed to the development of systems engineering as a distinct entity.

### **Cognitive systems engineering**

Cognitive systems engineering (CSE) is a specific approach to the description and analysis of human-machine systems or sociotechnical systems. The three main themes of CSE are how humans cope with complexity, how work is accomplished by the use of artifacts, and how human-machine systems and socio-technical systems can be described as joint cognitive systems. CSE has since its beginning become a recognised scientific discipline, sometimes also referred to as cognitive engineering. The concept of a Joint Cognitive System (JCS) has in particular become widely used as a way of understanding how complex socio-technical systems can be described with varying degrees of resolution. The more than 20 years of experience with CSE has been described extensively.<sup>[39][40]</sup>

### **Configuration Management**

Like systems engineering, configuration management as practiced in the defense and aerospace industry is a broad systems-level practice. The field parallels the taskings of systems engineering; where systems engineering deals with requirements development, allocation to development items and verification, Configuration Management deals with requirements capture, traceability to the development item, and audit of development item to ensure that it has achieved the desired functionality that systems engineering and/or Test and Verification Engineering have proven out through objective testing.

### **Control engineering**

Control engineering and its design and implementation of control systems, used extensively in nearly every industry, is a large sub-field of systems engineering. The cruise control on an automobile and the guidance system for a ballistic missile are two examples. Control systems theory is an active field of applied mathematics involving the investigation of solution spaces and the development of new methods for the analysis of the control process.

### **Industrial engineering**

Industrial engineering is a branch of engineering that concerns the development, improvement, implementation and evaluation of integrated systems of people, money, knowledge, information, equipment, energy, material and process. Industrial engineering draws upon the principles and methods of engineering analysis and synthesis, as well as mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems.

### **Interface design**

Interface design and its specification are concerned with assuring that the pieces of a system connect and inter-operate with other parts of the system and with external systems as necessary. Interface design also includes assuring that system interfaces be able to accept new features, including mechanical, electrical and logical interfaces, including reserved wires, plug-space, command codes and bits in communication protocols. This is known as extensibility. Human-Computer Interaction (HCI) or Human-Machine Interface (HMI) is another aspect of interface design, and is a critical aspect of modern systems engineering. Systems engineering principles are applied in the design of network protocols for local-area networks and wide-area networks.

### **Mechatronic engineering**

Mechatronic engineering, like Systems engineering, is a multidisciplinary field of engineering that uses dynamical systems modeling to express tangible constructs. In that regard it is almost indistinguishable from Systems Engineering, but what sets it

apart is the focus on smaller details rather than larger generalizations and relationships. As such, both fields are distinguished by the scope of their projects rather than the methodology of their practice.

### **Operations research**

Operations research supports systems engineering. The tools of operations research are used in systems analysis, decision making, and trade studies. Several schools teach SE courses within the operations research or industrial engineering department<sup>[citation needed]</sup>, highlighting the role systems engineering plays in complex projects. Operations research, briefly, is concerned with the optimization of a process under multiple constraints.

### **Performance engineering**

Performance engineering is the discipline of ensuring a system will meet the customer's expectations for performance throughout its life. Performance is usually defined as the speed with which a certain operation is executed or the capability of executing a number of such operations in a unit of time. Performance may be degraded when an operations queue to be executed is throttled when the capacity of the system is limited. For example, the performance of a packet-switched network would be characterised by the end-to-end packet transit delay or the number of packets switched within an hour. The design of high-performance systems makes use of analytical or simulation modeling, whereas the delivery of high-performance implementation involves thorough performance testing. Performance engineering relies heavily on statistics, queuing theory and probability theory for its tools and processes.

### **Program management and project management.**

Program management (or programme management) has many similarities with systems engineering, but has broader-based origins than the engineering ones of systems engineering. Project management is also closely related to both program management and systems engineering.

### **Proposal engineering**

Proposal engineering is the application of scientific and mathematical principles to design, construct, and operate a cost-effective proposal development system. Basically, proposal engineering uses the "systems engineering process" to create a cost effective proposal and increase the odds of a successful proposal.

### **Reliability engineering**

Reliability engineering is the discipline of ensuring a system will meet the customer's expectations for reliability throughout its life; i.e. it will not fail more frequently than expected. Reliability engineering applies to all aspects of the system. It is closely associated with maintainability, availability and logistics engineering. Reliability engineering is always a critical component of safety engineering, as in failure modes and effects analysis (FMEA) and hazard fault tree analysis, and of security engineering. Reliability engineering relies heavily on statistics, probability theory and reliability theory for its tools and processes.

### **Safety engineering**

The techniques of safety engineering may be applied by non-specialist engineers in designing complex systems to minimize the probability of safety-critical failures. The "System Safety Engineering" function helps to identify "safety hazards" in emerging designs, and may assist with techniques to "mitigate" the effects of (potentially) hazardous conditions that cannot be designed out of systems.

### **Security engineering**

Security engineering can be viewed as an interdisciplinary field that integrates the community of practice for control systems design, reliability, safety and systems engineering. It may involve such sub-specialties as authentication of system users, system targets and others: people, objects and processes.

### **Software engineering**

From its beginnings, software engineering has helped shape modern systems engineering practice. The techniques used in the handling of complexes of large software-intensive systems has had a major effect on the shaping and reshaping of the tools, methods and processes of SE.

## **PRODUCTION PLANNING AND CONTROL PLANNING**

Planning from the managerial point of view can be defined as the determination of what to do and how to do it. It can therefore, be said that planning is making decisions from among many alternatives.

- Planning includes all activities that establish a course of action to guide future decision making. It is part of the work of Operation Manager to know and define the objective of the organization, and policies, programs, and procedures for achieving the objectives. It involves overall strategy of achieving the organization objectives.
- Planning is a process of thinking ahead.
- Planning bridges the gap between where we are and where we want to be.
- Planning is the mental and intellectual work required before a physical effort take place.
- Planning is considered a manager's first responsibilities to the business and is a process whereby a future state is compared with the present and specific steps are formulated to achieve the goal.
- Planning is setting of business an objective which implies at least forecasting analyzing problems and making decision.
- Planning is the practical thinking, dreaming and scheming that it takes to isolate, determine and schedule the actions and the achievement required in order to attain our objectives. It is the formulation and development of the 'blue-print' we expect to follow.
- Planning is plotting the use of our time, resources and effort towards the realization of what we want to accomplish, and it is also the beginning of reality.
- Planning is investigating, forecasting, foreseeing, projecting, foretelling and endeavouring to penetrate tomorrow's invisible curtain.

### **Planning As a Measurement Function**

Planning is the function/activities of a manager in which helps the firm to:

- Determine the objective of the firm;
- Decides in advance what the manager wants to do.
- Explore the environment and forecast for changes.
- Making decisions from among any alternatives;
- Develop policies, procedures and plan to help achieve the objectives in view of the changing environment.
- Establish a course of action, thus guiding future decision making.

Planning essence is futurity which is an intellectual process of creative thinking and imagination which is very essential for the growth of an organization.

The nature of importance of planning can be looked at from the four major aspects of planning thus;

- Contribution to purpose and Objectives: It is used to facilitate the accomplishment of the purpose and objective in the enterprise.
- Primary of Planning: this is the first among function, since managerial operations are organizing, staffing, leading and controlling. These are used to support the enterprise objectives. Planning precedes the execution of all other managerial functions.

- Pervasiveness of planning: this is the effect of planning which is important for all other management function viz organizing, directing and control. Pervasiveness is to distinguish between policy making (the setting or guides for thinking in decision making) and administration, or between the “Manager” and the “Administrator” or “Superior”.
- Efficiency of Plans: The efficiency is measured by the amount it contributes to purpose and objectives as offset by the cost and other unsought consequences which is required to formulate and operate it.

### **Types of Plans**

The types of plan can be classified into 3 main Categories thus:

#### **CLASSIFICATION BY TIME AND DURATION**

There are three (3) major types of classification by time o duration thus;

- i. Long-Range Planning: This is between 5 to 10 years. It can also be refer to as capacity planning which can be sub-divided into two: *Facility Planning* and *Equipment Planning*. This can be in form of plant construction and location with product line design and development.
- ii. Medium or Intermediate Range Planning: This is between 2 to 5 years. It can also be referred to as Aggregate Planning, which can be sub-divided into three:
  - Use of facility;
  - Personnel needs; and
  - Sub-contractingIt can also be refer to as master schedule which can be subdivided two:
  - Material Requirement planning (MRP)
  - Disaggregation of Master Plan.
- iii. Short-Range Planning: This is between several months to year. Examples are inventory, goals, labour budget, job scheduling, production levels and purchasing.

#### **CLASSIFICATION BY BUSINESS FUNCTION OR USE**

Classification by business functions or use can be plans concerning the ;

- Sales Function;
- Production Function;
- Personnel Function;
- Finance Function and
- Carry other major Function

#### **CLASSIFICATION IN RESPECT TO BREADTH OR SCOPE**

The Classification in respect to breadth scope can be from the three types enumerated below thus;

- i. Policies – the policy decisions adopted can be in form of
  - i. *Whether to make or buy the product*: If the company cannot make a particular product or item they can decide to buy, which will be a short-run decision. It should be reviewed from time-to-time.
  - ii. *Whether Manufacturing will be intermittent or continuous*: the decision whether a product production will be intermittent or continuous depends on the characteristics of the products. Usually most production lie between continuous and intermittent.
  - iii. *Whether Manufacturing will be for stock or for order*: it depends on the key factor of firm’s policy regarding the time that can be allowed to elapse between receiving a customer’s order and

filling his order. Other factors can be; the value of product, the service expectation of the customer, the practices of competitions firms and the custom of the industry. Making to order means each order must be processed individually through production system.

iv. *Whether size the production order will be?* The determination of production size orders influences the choice of a production planning and control system in the same way as for sock or for order.

v. *Where the repair work will be done:* It is necessary to determine where the repair work will be done during manufacturing process. The repair of products are of three(3) types:

- Product found defective during the manufacturing cycle.
- Products that develop defects during the warranty period.
- Products that have developed defects because of normal wear and tear by the customer.

All the above problems should be taken care of, and that they are mutually independent.

## ii. Procedure

Procedure to be followed can be informed of:

- Standard operating procedure; and
- Dialing operation of company.

## iii. Methods

Methods to be followed can be informed of:

- Name and sequence of performing individual tasks(intra-dependent)

## STEPS IN PLANNING

The following are the steps which can be followed in planning process;

- i. There should be awareness that there is an opportunity: The awareness of opportunity to invest in a business must be known. This can be in relation to: the market, competition available; what customers want; the strength of the business and the weakness of the business.
- ii. Identification of the goal and objectives of the organization to build a solid foundation: Where we want to be and what we want to accomplish and when.
- iii. Considering Planning Premises: Looking at what environment – internal or external – will the plan operate?
- iv. Identify the alternative changing situation that may arise: Identify the alternatives and what are the most promising alternatives to accomplishing the objective of the firm.
- v. Compare alternatives in light of goal sought: is necessary to know which alternative will give us the best chance of meeting the firm goals at the lowest cost and highest profit.
- vi. Translate the opportunities into selected course of action: Selecting the course of action to pursue by the firm. This is the point where a plan is adopted – the real point of decision making.
- vii. Formulate Supporting Plans: In formulating the supporting plans this can be inform of looking at buying equipment. Buying materials, hire and train workers, develop a new product.
- viii. Revision of the initial plan to update the current experience: This is where one can numeric plans by making budgets. The overall budget of a firm represent the total of income and expenses, to obtain if the firm will break even and get profit or surplus or it will be run at a loss.

## PRODUCTION CONTROL

The basic concept of production control can be obtained by the review of some other people's work who has contributed to the growth of production control. It is however to be noted that "planning and control are inseparable" – the Siamese twins of management. Any attempt to

control without planning is meaningless since there is no way for people to tell whether they are going where they want to go (the result of task control) unless they first know where they want to go (part of the task of planning). Plans thus furnish the standard of control. Therefore, control has attracted so many definitions; some are reviewed below thus;

- Control is the checking of performance against plan.
- It is the power of authority to direct, order, or retrain.
- Management controls are ratios, standards, statistics and other basic facts needed by the Boards of Directors, the president and various members of staff in order to determine major decisions governing the administration of the organization's affairs.
- Control processes include all activities that try to match performance with established objectives.

Control Engineers control machines, industrial and economic processes for the benefit of the society. It is applicable to aeronautical, chemical, mechanical, production environmental, civil, and electrical and control engineering, rooted in feedback theory and linear system analysis and integrates networks a communication theories.

The decisions on whether or not to invest capital to reduce production cost or increase capacity are one of the most challenging problems that management has to face. A large investment may indicate a high associated risk. This risk may be minimized if more is known about effects of many factors and if one has the ability to manipulate these factors to evaluate different courses of action.

Production Control is the process of;

- Determining a manufacturing plan;
- Issuing information for its execution;
- Collecting data which will enable the plan to be controlled through all stages.

A major purpose of managerial control is to ensure that programs are carried out in such a way that objectives will be met successfully. Control is needed to achieve the following;

- i. Dispatching: It is the process of actually ordering works to be done.
- ii. Expediting: It is the follow-up of the following activity that checks whether plans are actually being executed.

In each aspect of production planning and control, we see some or all of the following.

- Key Issues; what are the key problem areas?
- Frame Work: How do these problems relate to other parts of production planning and control system?
- Technical consideration; what techniques or systems are useful in solving the problems?
- Managerial considerations; what organizational, managerial or technical changes are necessary to create an effective systems?
- Data Base: What is the underlying data base to support the system?
- Examples: How has effective systems been implemented in leading edge firm.

### **Production Planning and Control**

A production (or manufacturing) planning and control (MPC) system is concerned with planning and controlling all aspects of manufacturing, including materials, scheduling machines and people, and coordinating suppliers and customers. An effective MPC system is critical to the success of any company. An MPC system's design is not a one-off undertaking; it should be

adaptive to respond to changes in the competitive arena, customer requirements, strategy, supply chain and other possible problems

Production planning and control are usually used together. Planning the manufacture of products in the desired quantity and quality is a crucial issue in production management. However, even the best-conceived plans can go haywire because of delays, low inventories and machinery breakdowns. Consequently, there is a need for control over the operations to signal deviations from plans and trigger corrective measures.

There are three areas of influence on the production planning and control;

1. **Internationalization:** Growth in international markets has had a crucial impact on the MPC context. Global customer base and international suppliers have become a reality. The composition of supply chains change based on opportunities. This requires international, transparent and effective MPC systems.
2. **The role of the customer:** Meeting customer requirements and service demands is crucial. Hence, both product and process flexibility is needed to produce customized products at variable volume.
3. **Information technology:** Responding to global coordination and communication requirements calls for the deployment of information systems to link functionally disparate, geographically dispersed and culturally diverse organizational units.

### Scope

There are two interpretations regarding the scope of production planning and control:

1. According to the first approach, the planning of all materials, processes and operations ending with the finished product fall under the purview of production planning and control. Inventory control, scheduling of operations and the planning of required equipment are also included.

2. The second approach views planning as an aggregate overall concept. The starting point is the sales forecast or sales orders, then production capacity assessment is done and scheduling of operations is completed.

### Characteristics

A production planning and control system should match the needs of the firm. In designing the MPC system, the nature of the production process, the degree of supply chain integration, customer expectations and needs of the management should be taken into account. The MPC system should smoothly integrate with other company functions as well as the operations of other companies in the supply chain.

### Costs and Benefits

Initial costs of establishing a production planning and control system can be high. Ongoing operational costs can also be high given the number of professionals and resources such as computers, training and space needed. Moreover, an ineffective MPC system can even lead to the collapse of the whole business because of poor customer service, excessive inventory and misallocation of material, workers and equipment. On the other hand, successful implementation of a production planning and control system can have crosscutting benefits such as appropriate level of work-in-process, smooth production, rapid delivery times, economic production lot sizes and improved labor productivity.

## PURCHASING PROCESS

**Purchasing** is the formal process of buying goods and services. The **Purchasing Process** can vary from one organization to another, but there are some common key elements.

The process usually starts with a 'Demand' or requirements – this could be for a physical part (inventory) or a service. A requisition is generated, which details the requirements (in some cases providing a requirements specification) which actions the procurement department. A

Request for Proposal (RFP) or Request for Quotation (RFQ) is then raised. Suppliers send their quotations in response to the RFQ, and a review is undertaken where the best offer (typically based on price, availability and quality) is given the purchase order.

Purchase orders (PO) can be of various types, including:

- Standard - a onetime buy;
- Planned - an agreement on a specific item at an approximate date; and
- Blanket - an agreement on specific terms and conditions: date and quantity and amount are not specified.

Purchase Orders are normally accompanied by Terms and Conditions which form the contractual agreement of the Transaction. The Supplier then delivers the products/service and the customer records the delivery (in some cases this goes through a Goods Inspection Process). An invoice is sent by the supplier which is cross-checked with the Purchase Order and Document which specifying that the goods received.

The activity of acquiring goods or services to accomplish the goals of an organization.

The major objectives of purchasing are to;

- (1) maintain the quality and value of a company's products,
- (2) minimize cash tied-up in inventory,
- (3) maintain the flow of inputs to maintain the flow of outputs, and
- (4) strengthen the organization's competitive position.

Purchasing may also involve;

- (a) development and review of the product specifications,
- (b) receipt and processing of requisitions,
- (c) advertising for bids,
- (d) bid evaluation,
- (e) award of supply contracts,
- (f) inspection of good received, and
- (g) their appropriate storage and release.

## **DESIGN OF METHODS/WORK/TIME STUDY AND WORK MEASUREMENT**

### **Design Methods**

Methods in engineering can be defined as a body of knowledge that deals with the analysis of the methods and equipment used in performing a job. It can also be referred to as the design of the optimum methods, and standardisation of the proposed method of performing a job. This can also be referred to as motion study, operation analysis, work study, or job design. This can also be closely related to work measurement

The application of methods engineering are:

- The design of a new plant
- The design of a new process
- To improve an existing process, and
- To improve an existing work place

Work methods is the critical study or ways of doing work and method usually arise where there are

- Bottlenecks – which generates high work in progress, long delivery times or unbalanced work flow;
- Idle plant/people – which usually give rise to underutilization of the resources;
- Poor morale – this is evident by petty or trivial complaints; and inconsistent earning.

Methods engineering historical perspective can be traced to Frank B and his wife Lilvan M. Gibreth who developed the tool known as “motion study”. In searching for the best ways he made use of:

- The process chart;
- The right – and left hand operation chart
- Micromotion study
- Therblings; and the choronocylegraph

### **Approach to Methods Design**

The following steps are to be followed in other to ensure that the optimum method is found in carrying out method study

- Identify the problem and analyse it – is necessary to look for all information about the problem and used the correct analysis technique. If it a new innovation, you can select the task to be studied
- Question the present method – if the present method is available, look for information on it, and question it, and determine the principle violated.
- Formulate a proposed method – this is done by looking at all the principles of methods engineering and bringing them together to work for the task.
- Standardise and apply the new method – the new methods identified are standardised and applied to see its functionality.

### **Tools for method analysis**

The tools for methods analysis are of visual observation methods. All facts require recording preferably as the time place of occurrence. There are various recording methods, and some common ones are:

1. Process chart

The American National Standard Industrial Engineering Terminology defines a flow process chart as; “a graphic symbol representation of the work performed or to be performed on a product as it passes through some or all of the stages of a process. Typically, the information included in the chart is quantity, distance moved, type of work done (by symbol with explanation) and equipment used. Work times may also be included”.

To analyse the movement of a product, man, or paper work, the flow process chart is very useful in providing step-by-step graphical representation.

There are types of the process charts.

- Outline process chart, and
- Flow process chart

In the outline process chart, the overall picture or the sequence of events and of the introduction of materials in a process is given by recording, operations and inspection symbols.

In the flow process chart, more detail is provided. All process chart symbols are used. The activity and storage that take place on that part as it moves from one stage of completion to another. The process flow chart symbols are:

These are chart where two or more activities which are proceeding simultaneously are shown on a common time scale. Under this chart, there are two basic charts, they are;

- Multiple Activity Chart: when operations involving the time relationship between or combination of man and machine, two or more men, machines or materials. It provides a convenient techniques or analysing the combined activity. A vertical column is erected for each activities and work performed as shading within the column. Time is recorded on the left and a brief description of the continuity to the right. From the chart the ratio of then non-working time can be determined and an attempt at balancing can be made.
  - The Simultaneous Movement Chart or SIMO Chart: the above chart is utilised under micromotion study originated by Frank B. Gilbreth for job analysis and job improvement. Micromotionstudy makes use of motion picture taken at a constant and known speed. It provides a valuable technique for making minute analysis of those operations that are short in cycle, contain rapid movements, and involve high production over a long period of time. The procedure adopted when performing micromotion study is:
    - Take the motion pictures of the operations;
    - Analyse the resulting film; and
    - Prepare a SIMO (Simultaneous Motion Cycle) chat from the result obtained from the firm analysis
  - The movement of two or more parts of a worker's body are recorded. The movements are generally of very short time duration (Such as 1/2000 minute, 1/10 minute, 1 second). The preparation of SIMO chart normally requires a frame-by-frame analysis of a cine film of work being utilised. The elements of work or the firm can be analysed by the use of "therblings" or basic body motion.
  - There are 17 therblings which are not considered to be the smallest subdivision into which human activity can be subdivided, but known and used widely. The 17 therblings with their symbols colours and definitions are show below
2. Movement Charts: there are different types of movement cahrt available. Some types available are:
- Travel Chart: this is number of movement made over a period of time is recorded
  - Flow diagrams: displays the work place and location of various activities drawn to scale equivalent to the flow process chart drawn upon a scale drawing of the workplace
  - String diagrams: scale drawing mounted on a cored panel is used. A preliminary survey for locating the terminal points and a fine string is done, before a fine string is wound to represent movements. Supplementary pins are inserted where direction of movement change is required. Unwinding will show vividly the distance traversed and the fruits in the layout which cause bottlenecks etc.

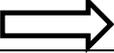
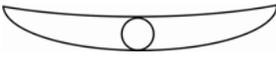
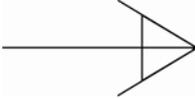
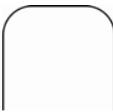
Symbol	Name	Activities Represented
	Operation	Activity where operation is carried out
	Ancillary	If there are ancillary operation which is not a major activity you which
	Transportation	This is a change in location of object from one place to another
	Inspection	This is the examination of object to check on the quality or quantity characteristics
	Permanent Storage	This is done to retain an object in which it is protected against unauthorised removal
	Delay or temporary storage	This is retention of object temporarily waiting the next activity. There is no need for authority to perform next activity

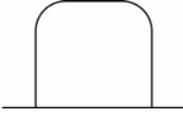
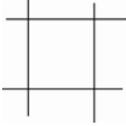
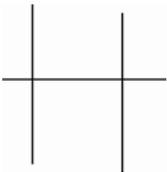
Fig 1: Symbol used for process charting

3. Time Scale Chart

DESCRIPTION	TIME						DESCRIPTION

Fig 2: Multiple Activity Chart

No	Name of Symbol			Colour	Activity Represented
1	Search	Sh		Black	When the eyes or hands are trying to pick or find something
2	Fine			Grey	When one object is being picked or selected among several others
	Select	St		Light Grey	
3	Grasp	G		Lake Red	Taking hold of an object

4	Hold	H		Gold Ochre	Retention of an object in a fixed position
5	Transport Loaded	TL		Grass Green	Moving of an object from one place to another
6	Position	P	9	Blue	Align an object preparatory to fitting it into some location
7	Assemble	A		Violet	Combining one object with another
8	Use	U		Purple	The using or manipulating a tool, control or device
9	Disassemble	DA		Light Violet	Separating two objects which were combined
10	Inspect	O		Burnt Ochre	An examination of an object to find out its quality, such as size, shape or colour
11	Pre-position	PP		Sky blue	Locating an object in a predetermined manner
12	Release Load	RL		Carmine red	It occurs when the hand lets go off an object
13	Transport empty	TE		Olive Green	Is the moving of the empty

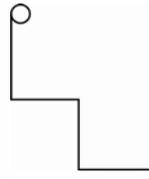
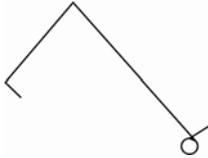
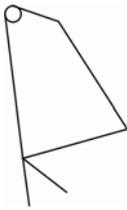
					hand while reaching for something
14	Rest for Overcoming fatigue	R		Orange	It happens when a worker pauses to overcome the fatigue from previous work
15	Unavoidable Delay	UD		Yellow Ochre	A delay by body member which is beyond the control of the operator
16	Avoidable Delay	AD		Lemon Yellow	A delay by body member which is within the control of the operator
17	Plan	Pn		Brown	It is a delay in a motion pattern while the operator decides how to proceed

Fig 3: Therblig Symbols and Definitions

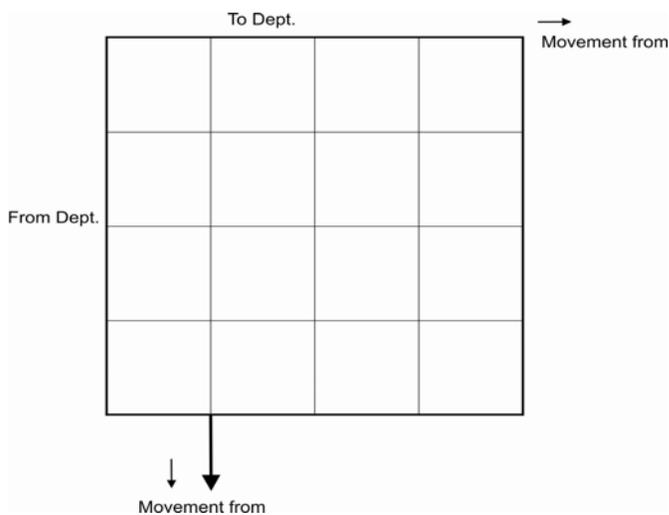


Fig 4 Travel Chart

## **Design of Work Study**

Work study can be defined as a management service based on those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts and which lead to the systematic investigation of all resources and factors which affect the inefficiency and economy of the situation being reviewed in order to effect improvement.

Work study attains its benefits through, firstly,

- Investigation of the current situation; then
- Examine apparent weakness (e.g. poor performance by an operating team or machine or the highest cost of a job).

This diagram is followed by the determination and introduction of appropriate improvement in operating methods. The investigation and review will cover operating methods, layout, supply and usage of materials, availability of ancillary services, for example materials handling, organisation of work, progress control etc. and the potential effect of the investigation on overall cost and profitability.

Due to the resentment that may arise from advice of work study engineer, by various organ in the factory, it is advisable that he takes positive step to carry everybody along, especially those whose work are to be studied. No survey.

Work study include

- Method study; and
- Work measurement

## **Work measurement**

Work measurement (commonly referred to as time study) is the field of study that attempts to quantify the amount of work, in terms of time required, to perform a task. The efficient operation of an organisation can only be predicated on some knowledge of how long it takes to make a product or perform a service. A qualified worker, who can do this, is the one who has the necessary physical and mental attributes and has acquired the necessary skill. The most important technique used in work measurement is the

- time; and
- Motion study

The origin of work measurement can be traced back to Fredrick W. Taylor who introduced work measurement or time study as an essential part of scientific management in the Mid Vale Steel Company in 1881. The question then was:

- What is the best way to do the job?
- What equipment should be used?
- What is fair day's work?

Which he tried to find solution to. In practice now, the technique used can be traced to Frank Gilbreth early in this century. Without time estimate the:

- Cost could not be estimated, as price could not be quoted correctly
- Budgets could not be made
- Performance evaluation will be difficult since there would be no basis for comparison
- Plans and merits for incentive become unpredictable

There are four accepted ways to derive the time required in the performance of a human task. They are:

- i. Time study (the use of stopwatch and micromotion analysis)

- ii. Elemental standard time data;

### **Time study**

Time Study is a direct and continuous observation of a task, using a timekeeping device (e.g., decimal minute stopwatch, computer-assisted electronic stopwatch, and videotape camera) to record the time taken to accomplish a task and it is often used when:

- there are repetitive work cycles of short to long duration,
- wide variety of dissimilar work is performed, or
- process control elements constitute a part of the cycle.

The Industrial Engineering Terminology Standard defines time study as "a work measurement technique consisting of careful time measurement of the task with a time measuring instrument, adjusted for any observed variance from normal effort or pace and to allow adequate time for such items as foreign elements, unavoidable or machine delays, rest to overcome fatigue, and personal needs."

#### **Purpose**

The main objective of a time and motion study is to determine reliable time standards for the efficient and effective management of operations. Through the establishment of reliable and accurate time standards, companies can better define their capacity or output, thus increasing the efficiency of equipment and obtaining optimum utilization of the workforce.

Time standards can be used to investigate the difference between actual and standard performance and take appropriate action where necessary. It can also be used to facilitate job design as a basis for comparing different work methods, introducing sound production controls, designing an efficient workplace layout, and balancing between work schedules and available manpower. Other benefits include budgetary control, development of incentive plans, and ensuring that quality specifications are met.

#### **Direct time study procedure**

Following is the procedure developed by Mikell Groover for a direct time study:

1. Define and document the standard method.
2. Divide the task into work elements.  
Steps 1 and 2 These two steps are primary steps conducted prior to actual timing. They familiarise the analyst with the task and allow the analyst to attempt to improve the work procedure before defining the standard time.
3. Time the work elements to obtain the observed time for the task.
4. Evaluate the worker's pace relative to standard performance (performance rating), to determine the normal time.  
Note that steps 3 and 4 are accomplished simultaneously. During these steps, several different work cycles are timed, and each cycle performance is rated independently. Finally, the values collected at these steps are averaged to get the normalised time.
5. Apply an allowance to the normal time to compute the standard time. The allowance factors that are needed in the work are then added to compute the standard time for the task.

#### **Time and motion study**

A **time and motion study** (or **time-motion study**) is a business efficiency technique combining the Time Study work of Frederick Winslow Taylor with the Motion Study work of Frank and Lillian Gilbreth (not to be confused with their son, best known through the biographical 1950 film and book *Cheaper by the Dozen*). It is a major part of scientific management (Taylorism). After its first introduction,

time study developed in the direction of establishing standard times, while motion study evolved into a technique for improving work methods. The two techniques became integrated and refined into a widely accepted method applicable to the improvement and upgrading of work systems. This integrated approach to work system improvement is known as methods engineering and it is applied today to industrial as well as service organizations, including banks, schools and hospitals.

Time and motion study have to be used together in order to achieve rational and reasonable results. It is particularly important that effort be applied in motion study to ensure equitable results when time study is used. In fact, much of the difficulty with time study is a result of applying it without a thorough study of the motion pattern of the job. Motion study can be considered the foundation for time study. The time study measures the time required to perform a given task in accordance with a specified method and is valid only so long as the method is continued. Once a new work method is developed, the time study must be changed to agree with the new method.

## Factory Planning and Material Handling and Industrial Standardization



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## Planning a Factory

### PROCEDURE

Part One: The Preliminary Plan

1. Use the Factory Planning Guide to help you begin your plan.
2. Develop a company (group) statement of your preliminary ideas about how to meet each of the agreed-upon needs for a factory on the island. Reflect on what you have learned throughout the year.

Use your science notebook and this student book as resources to help you plan.

3. You may want to identify several alternatives to choose among later. Your company’s statement should help you identify additional information that you will need to make final decisions and to prepare the environmental impact report.
4. Include rough maps and/or sketches to illustrate your project.

### FACTORY PLANNING GUIDE

### **1. New construction**

Glue production will require factory buildings. Your plan may also call for additional roads, docks, or other construction for transporting the raw materials and the finished product. Describe everything that will be built as part of your project.

### **2. Material resources: Milk**

You will need a source of milk. There are three existing dairy farms on the island. A typical farm there covers nearly 28 hectares (70 acres) of land. Each farm has about 500–600 cows on the dairy, or 30–38 cows per hectare (12–15 cows per acre) of pastureland. The number of cattle is restricted to help preserve the pasture and the groundwater below it. At any given time, there are 500 cows involved in daily milk production.

The dairy produces 20,280 liters (5,500 gallons) of milk per day, or 41 liters (11 gallons) on

## **Planning a Factory**

### **PROCEDURE**

Part Two: Environmental Impact Report

Your environmental impact report should be a balanced presentation of both the negative and positive impacts of the factory on the natural and human environment of Pinniped Island. Your company will have

10 minutes to present its plan to the council. Your plan will be rated according to how well it considers community concerns. In preparing your report:

- Give careful consideration to the background information provided to the Town Council
- You are encouraged to add additional information to your report to strengthen your presentation.
- Cover at least the seven items listed below.

#### **1. Factory proposal**

Describe your factory in detail. Consider the entire life cycle of the glue, from obtaining the materials needed for packaging and shipping the product to its final market. Choose and justify the site of your factory. Your plan should describe the proposed physical layout of the factory and the chemical interactions that the factory will use. If you plan to build power plants, roads, docks, or other facilities on the island, you should indicate the locations of these facilities.

#### **2. Existing environment**

Where will you locate the factory? Describe the environment as it now exists.

#### **3. Factory impact on the natural environment**

Describe how your project will impact the natural environment.

Include both positive and negative effects.

Looking at the following aspects of the natural environment as well as any additional topics you think are applicable.

- a. surface water
- b. groundwater
- c. vegetation
- d. animal life

#### **4. Factory impact on the human environment**

Describe how your factory will impact the human environment.

The “human environment” refers to any feature of the environment related to human activity, from buildings and cities to economic, social, and political systems. Your report should include the following areas as well as any additional areas that you think are important.

- a. water supply
- b. transportation systems

- c. waste systems
- d. community organizations (such as schools, recreational facilities, housing, hospitals)
- e. economic factors
- f. quality of life (such as noise, lighting, air, visual environment, factors that could involve health risks)

#### **5. Mitigating impacts**

Describe how you plan to mitigate (lessen or compensate for) any negative impacts you described in Sections 3 and 4. Also describe any impacts that cannot be mitigated.

#### **6. Summary statement**

Write a brief statement describing the major trade-offs that you encountered in developing your plan. Indicate why you think that your plan is the best overall factory plan possible.

#### **7. Resources**

Describe the resources that you used in preparing your report.

## **MANUFACTURING ENGINEERING AND MACHINE TOOLS**

### **Manufacturing Engineering**

Manufacturing which comes from Latin words manus (hand) and facere (to make), to include the following definitions;

- As to produce (goods) in large numbers;
- As industry that makes automobiles, books, clothing, furniture, paper, pencils and thousands of other products;
- Making, produce goods etc, on a large scale by machinery;
- As the one that converts raw materials into industrial standard stock which is further processed into finished products.
- As the transformation of materials and information into goods for the satisfaction of human needs.

Manufacturing is as old as man. Early man, fully aware of the limitations of his physiological make-up and conscious of the need to survive, realized that he could not survive the harsh environment in which he found himself without the manufacture of tools. Hence, the development of different tools and methods to make life comfortable for human race. Manufacturing can be considered as a system in which products design is the initial stage and the delivery of finished products to market is the final output. Manufacturing integrates many disciplines in engineering and management.

Manufacturing can be divided into three major elements;

- Changing the form of materials to those suitable for other processing or make them useful products.
- Providing a structure, such as company, which effectively organizes resources and use them to produce products;
- Durable or non-durable goods.

### **ROLE OF MANUFACTURING ENGINEERS**

The role of Manufacturing Engineers can be summarized thus;

- To bring the ideas and designs into reality by proper selection of material, machine, and manufacturing process;
- To have the thorough knowledge of material sciences, design, and manufacturing processes;
- To keep the production competitive, he must know how to select the appropriate tools and machines;
- He must see the whole production process, both technically and economically;
- He must be able to forecast or predict the likely problems to be encountered in the production of a particular material;
- He must have a good knowledge of the new tool now in use like computers which is now in great use in all the manufacturing sector; and

- He must be fully aware of the use of optimum cutting speeds, feeds, and dept of cut, selection of proper cutting tool materials.

## **Machine Tools**

There are different types of machines used in the machining processes in the workshop. Some of these machines will be treated in this chapter. For full details of this topic, you can see Metal Cutting machine tools published by the same author. Therefore, Some of the topic cover red by this chapter nine includes;

- Hole Production Machines;
- Turning Machines;
- Capstan or turret lathe;
- Shaping Machines;
- Grinding and Micro finishing Machines; and
- Milling Machines.

The machines are treated below thus;

### **PRODUCTION MACHINES**

Hole production in the machine shop is done with the aid of machines. Some of these machines are specially made to produce holes, some can also perform other operations in addition to the production of holes. For example, Centre Lathe machine can produce holes and also carry out other functions. But this chapter will treat basically the machines designed to produce holes.

### **DRILLING MACHINES**

Drilling Machines are considered to be important machines used by the Fitter/Machinist in his daily operations to cut a round hole into or through the material or job given. The machinist may like to produce small holes and he may not be interested in using the standard machines available, he may employ the use of portable drilling machine treated below.

#### **Portable Drilling Machine**

Portable Drilling Machine can be called

- (i) Hand drill or
- (ii) Breast drill,

These are small drilling machines used in the machine shop to produce holes. It is also very useful for the local fitters and mechanics.

Hand drill can be operated manually or fitted with electric motor called electric hand drill. Hand drill is capable of drilling hole of about 8mm diameter, while that of a breast drill with two speed can drill a hole to about 12mm diameter.

The hand drill powered by electricity should be carefully used. It is necessary to stop' the use at intermittent intervals, to disallow overheating of the drill in use. To minimise/prevent overheating, coolant can be used where applicable and practicable.

The figure 10.1 below shows the diagram of portable hand drilling machine.

It is noteworthy that the size of the drilling machine is the maximum diameter of holes it can drill using twist drill. The size can also be determined from the centre of the spindle to the nearest point on the column of the drilling machine.

Drilling Machines have been developed from the hand and breast drill type to more complicated different types. Other standard drilling machines are:

- (i) Sensitive or Table Drilling Machine
- (ii) Pillar or Upright Drilling Machine
- (iii) Radial Arm Drilling Machine
- (iv) Multi-spindle Drilling Machine
- (v) Deep - Hole Drilling Machine
- (vi) Turret - Drilling Machine

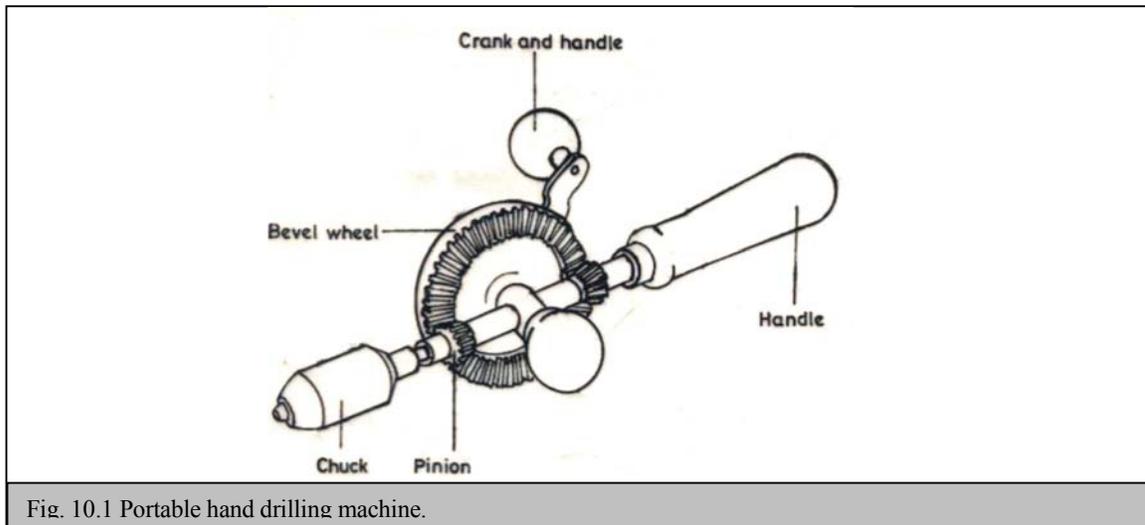


Fig. 10.1 Portable hand drilling machine.

### Sensitive or Table Drilling Machine

The sensitive drilling machine can also be called table drilling machine, the name differs from one author to the other. Some call it sensitive because the feed is human touch which is by hand, and, some call it bench, because it is usually placed or mounted on the bench. Whatever the name, they are still referring to the same machine.

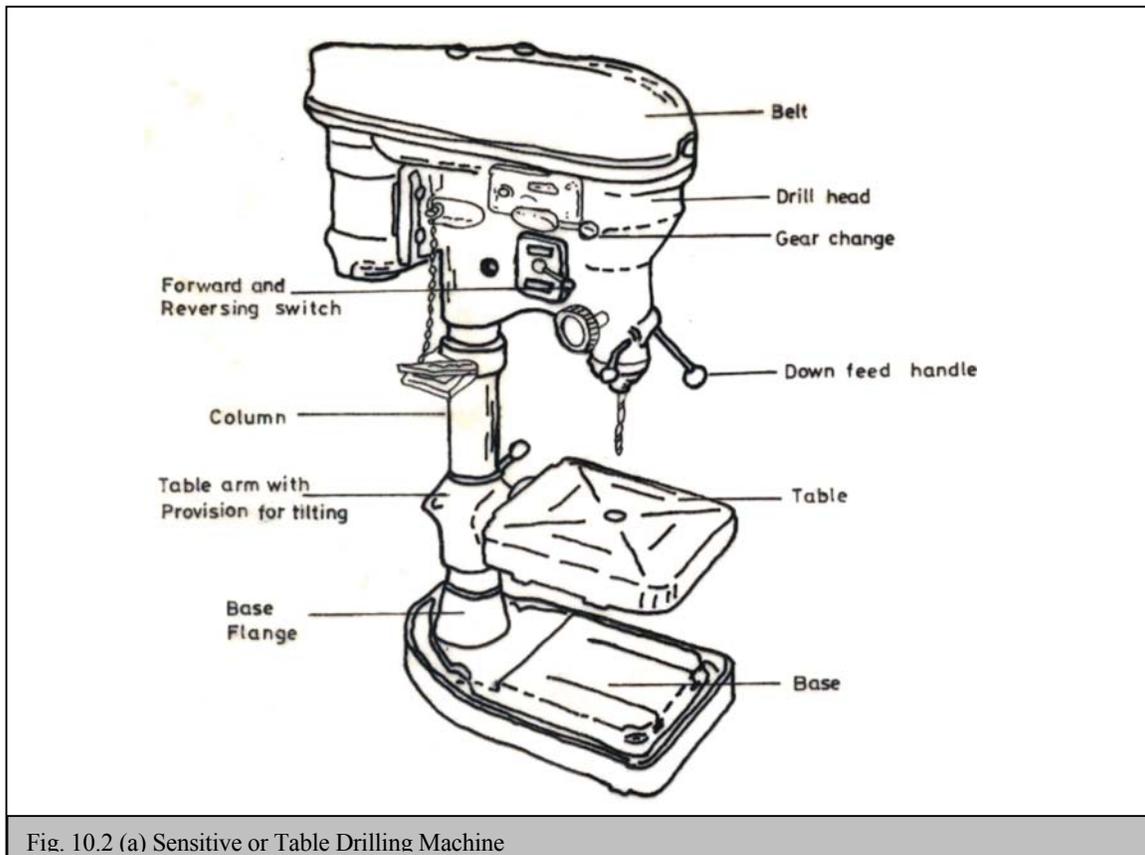


Fig. 10.2 (a) Sensitive or Table Drilling Machine

### Pillar or Upright Drilling Machine

The Pillar or Upright drilling machine is the floor type of the sensitive drilling machine. The pillar drilling machine is larger in size and heavier, it is capable of drilling large holes than 12mm diameter (drill sizes up to 50mm diameter), in addition to drilling the smaller holes performed by the sensitive drilling machine. It has dual feeds, that is, it can be fed manually and also use a power feed. This enables the machine to be able to produce smaller diameter holes using manual feed and larger holes using automatic feed.

#### **The Radial Arm Drilling Machine**

This machine is larger than both sensitive and Pillar Drilling machines. It is designed in such a way to carry a larger drill and deal with a larger work.

The radial arm drilling machine size is the length of the arm measured from the centre of the spindle to the edge of the column.

The major advantage of this machine is its ability to move its arm which carries the spindle head and can be swivelled about the vertical column. This enables it to be located at any point along the arm. This allows the work to be covered on the table without necessarily moving the table or the work.

The arm is also capable of being rotated in the horizontal plane. It can be raised or lowered to suit the job and the machinists' desire.

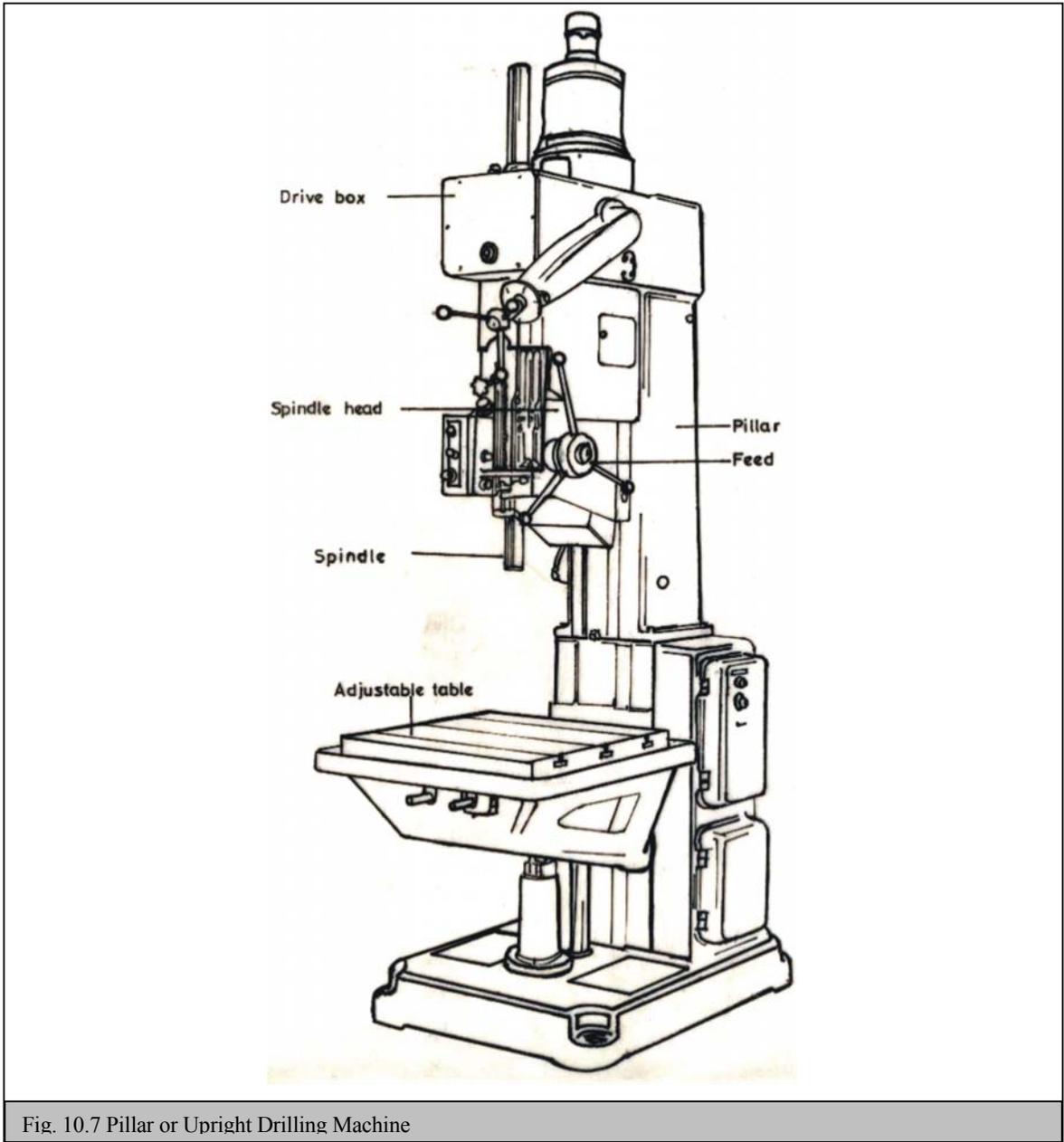


Fig. 10.7 Pillar or Upright Drilling Machine

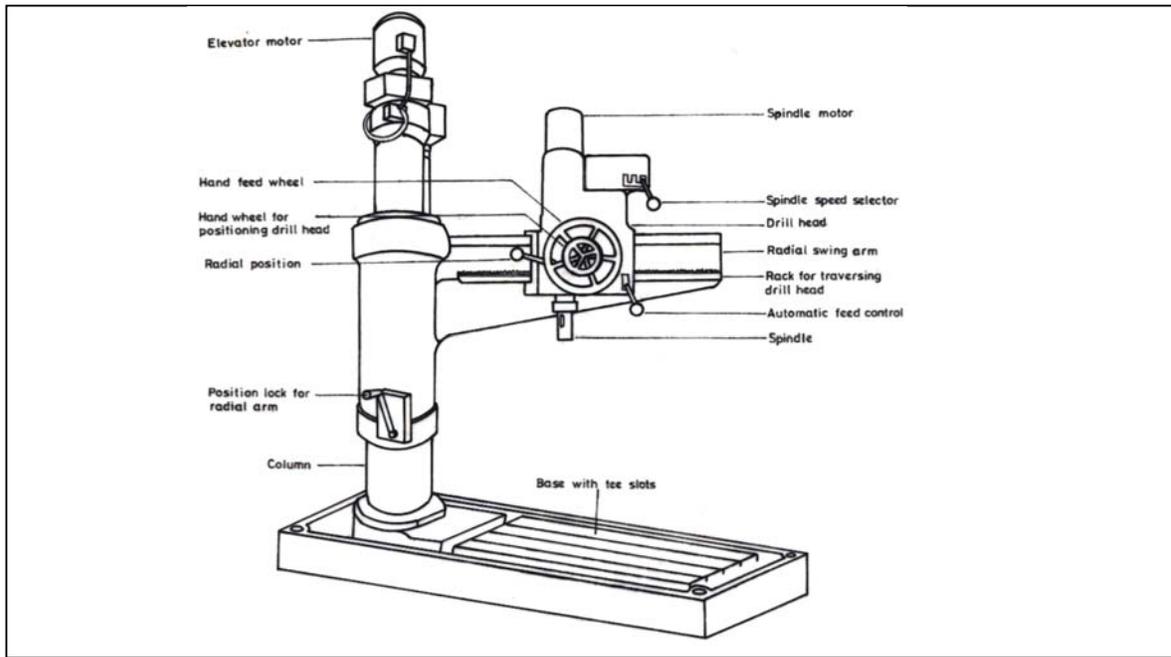


Fig. 10.8 Showing Radial Arm Drilling Machine

### Twist Drill

Twist Drill is the most widely used drill in the manufacturing or production of hole. It is a tool which use rotary - end cutting tools having one or two cutting lips and two or more helical or straight flutes which are used for the removal of chips and also to admit the cutting fluid which is used to lubricate the tool when cutting. The helical flutes provide rake angle which will be unaffected by continual sharpening.

Twist Drill can be made from the following materials;

- Carbon steel (hardened and tempered)
- High speed steel (with molybdenum or cobalt added for hardness)
- Carbon steel with the cutting edges of durable tungsten-carbide.

Out of the three mentioned above, the rest majority of twist drill are made from high speed steel. Because of the characteristics of "red hardness" - that is, the tendency to retain its hardness at very high temperatures.

The third one also possesses the quality mentioned above but is more costly than the second one.

From figure 30, one can easily observe that the drill has three major important parts;

**-Shank:** Twist drill are specified according to the end by which they are held (called shank). Shank is used to provide the drive. It can be taper or parallel as shown in fig. 30. The taper shank are mounted directly, while the parallel shank requires the use of key type drill chuck which is self centering into drill spindle or taper sleeve.

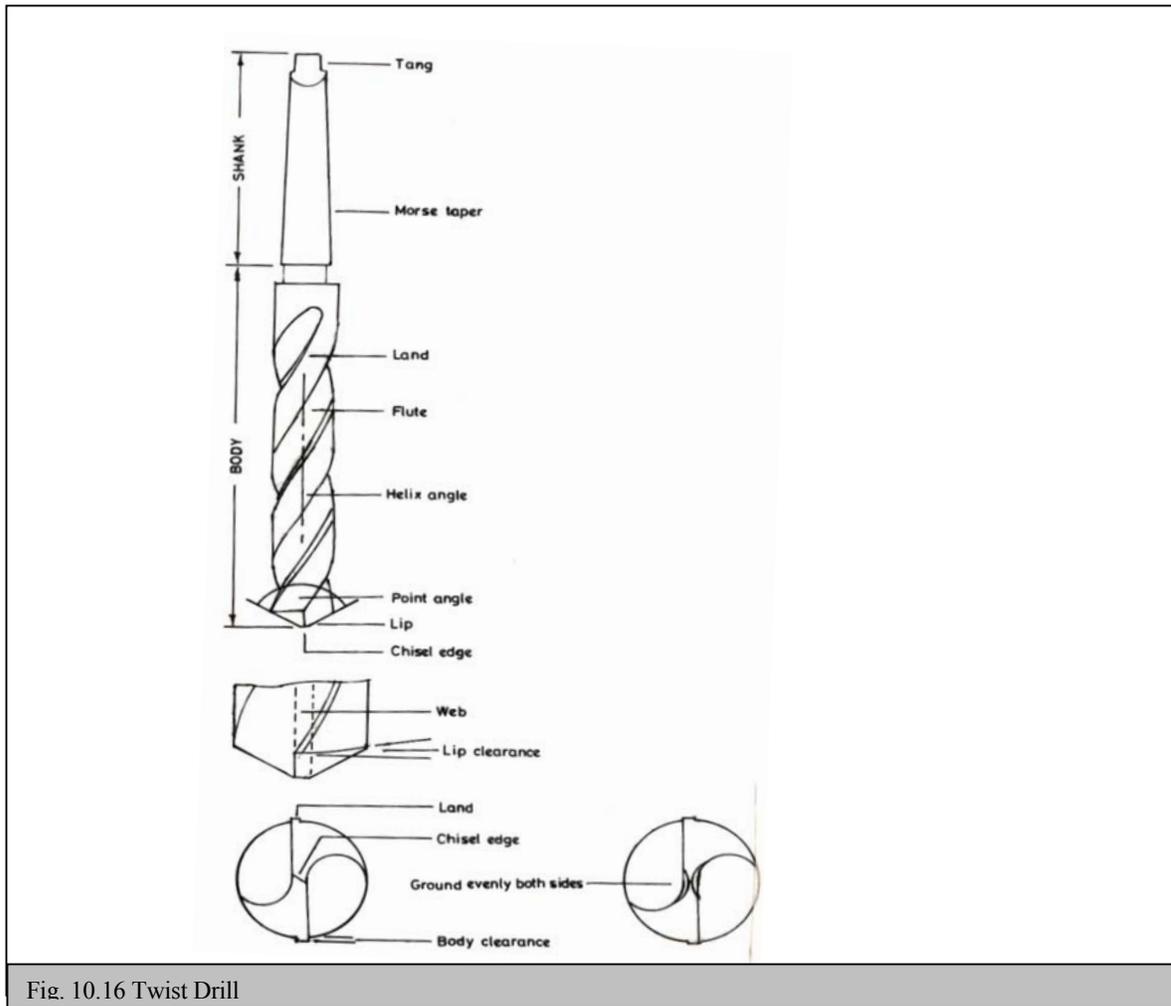
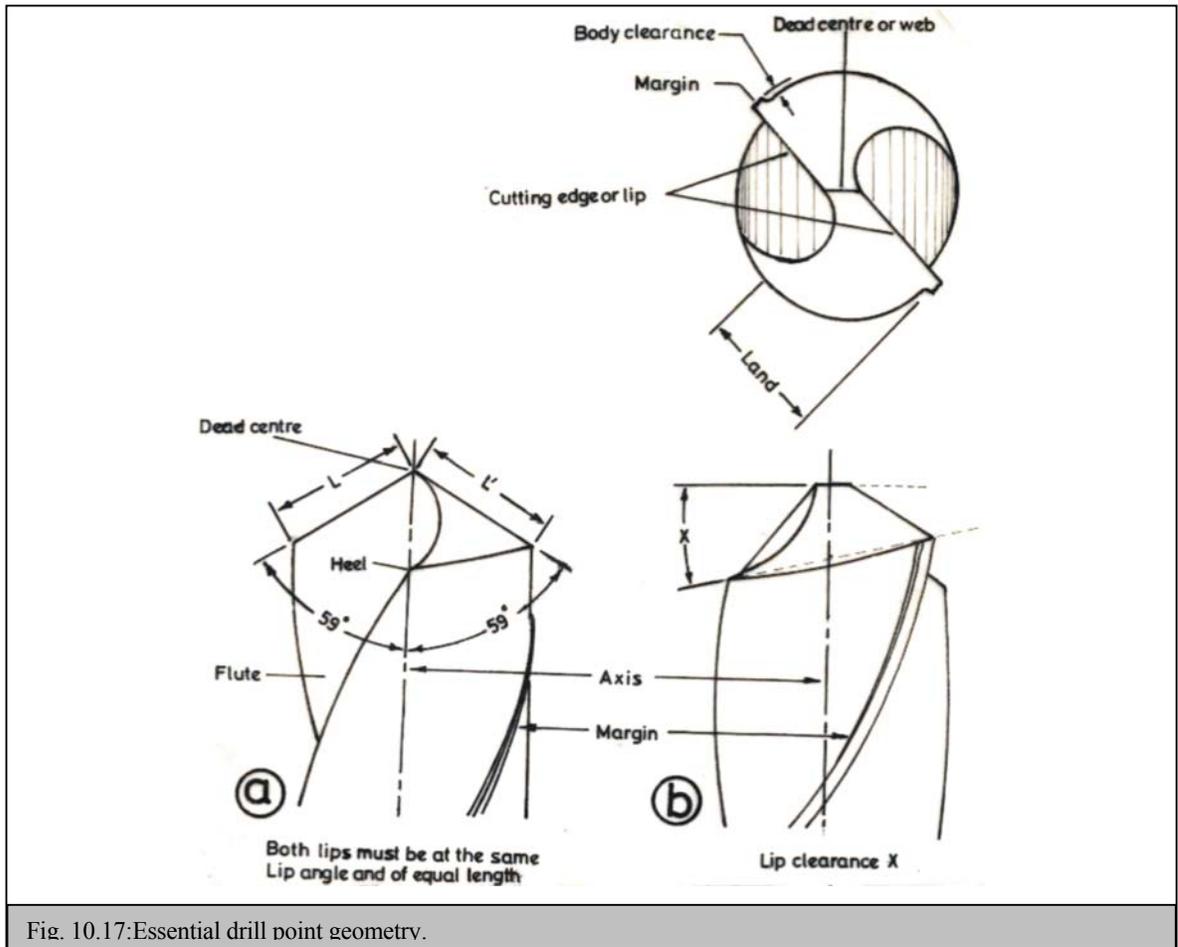


Fig. 10.16 Twist Drill

Small drills up to 3mm diameter are usually made with parallel shank and larger drills with taper shank because of greater torque involved when drilling larger holes.

**-The Body:** It is made in such a way that it tapers slightly in diameter from tip to the shank, to provide clearance for the escape of the swarf when drilling a deep hole.

**-The Point:** The point is the entire cone-shaped cutting end. The point accommodate the point angle, the lip, and the chisel edges, as shown in figures 10.16 and 10.17. Apart from the three major important parts, the drill is also provided with small land in order to reduce friction on the bearing surface.



It is better to use the recommended point angles for different materials available. Some of the recommended point angles are shown in figure 10.18. If followed, it will prolong the life of the drill and the materials can be easily drilled.

### Twist Drill Grinding

The essential drill point geometry is shown in figure 31 and the recommended point angle for different types of material in figure 32. It is necessary and essential that both lips must be at the same lip angle and equal length.

When sharpening or grinding a drill, the above mentioned points, that is the correct point angles, the equal length of the cutting edges and the correct clearance angle must be maintained.

Many skilled Technologists, Technicians or Craftsmen prefer to grind drill by hand on the double ended grinding machine available in the machine shop, but under no circumstances should large diameter drills be hand sharpened without the use of grinding attachment. This enables the Machinists to attain a better results.

### Drill Chucks

There are various methods employed in holding tools or drill on the drilling machine. It is possible to hold the taper shank directly to hole of the drilling machine spindle or into a tapered sleeve. (see fig. 10.5).

The most commonly used chuck is three jaw self centering chuck. The outer sleeve is threaded and when rotated, it moves axially along the chucks body. When the sleeve is screwed up, the conical surfaces cause the jaws to close the drill, and vice versa. There are two major types of this chuck used;

-Three Jaw self - centering chuck (hand operated); Hand is used to operate or tighten this type of chuck. It is used for smaller or lighter job (fig. 10.4a).

-Three Jaw self - centering chuck (Key operated), uses key to tighten this type of self centering chuck. The principle used is that of rack on the chuck sleeves. This type is capable of holding larger job and more firmly than hand operated type. The ability allows it to hold drills up to 12mm diameters. Drills above their size are usually supplied with morse taper shank, which fits directly to the machine spindle. (see fig. 10.4b for key operated chuck).

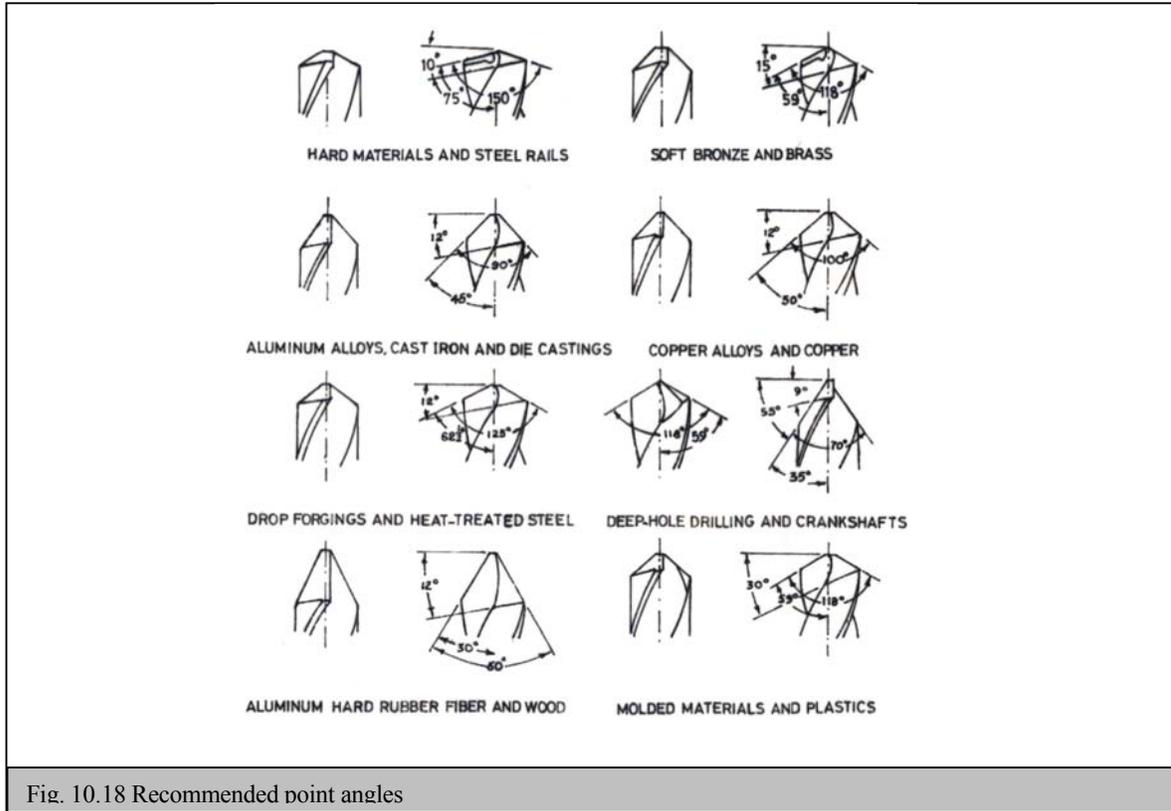


Fig. 10.18 Recommended point angles

**Methods of Layout/Holding for Drilling**

Drilling machine is used to produce hole. There are a lot of forces and torque involved in shearing the metal (most especially during the breaking through on the work), before hole can be produced. Therefore, it is very important that work should be securely held in the drilling machine during the operation. Unless work is so large and heavy that it cannot move or be rotated during the operation; then it may not require clamping.

In drilling, the method of holding or clamping of the job varies, but we shall deal with the most common methods;

**-The Machine Vice**

This is the most convenient way of holding work for drilling. The vice can be bolted to the table, this provide more effective gripping.

There are some precautions to be observed when using the machine vice. To avoid vibration, the work must be supported by parallel strips. Great care must also be taken so as not to allow the drill from damaging the surface of the vice when drilling.

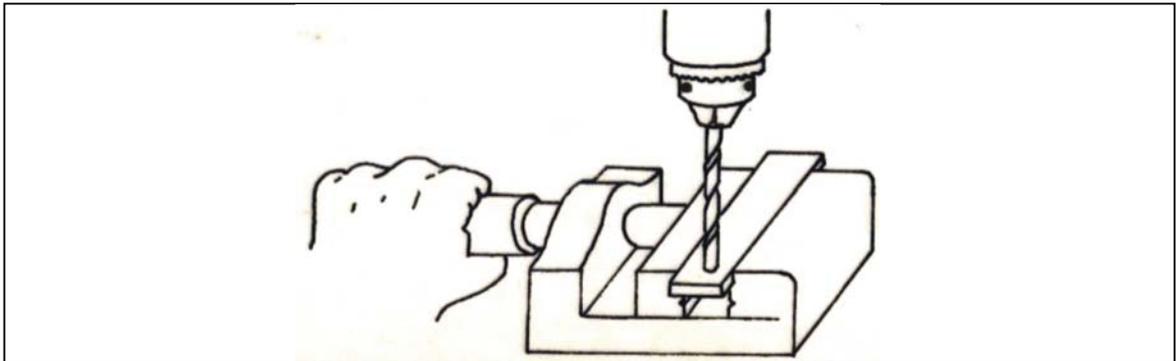


Fig. 10.19 Machine Vice in Use.

**-Using an Angle Plate**

The clamping of job to an angle plate is done when awkward shapes or castings have to be drilled. The angle plate is used to bring the work in correct alignment with the drill.

**-Using Vee Block**

The cylindrical or round objects which cannot be conveniently held with the other methods of holding are conveniently held in position for drilling using Vee block, as demonstrated in figure 10.20 below.

Extra care must be observed by securing the work firmly in the Vee block, so as to disallow the tendency of the work swinging around when the drill is trying to penetrate.

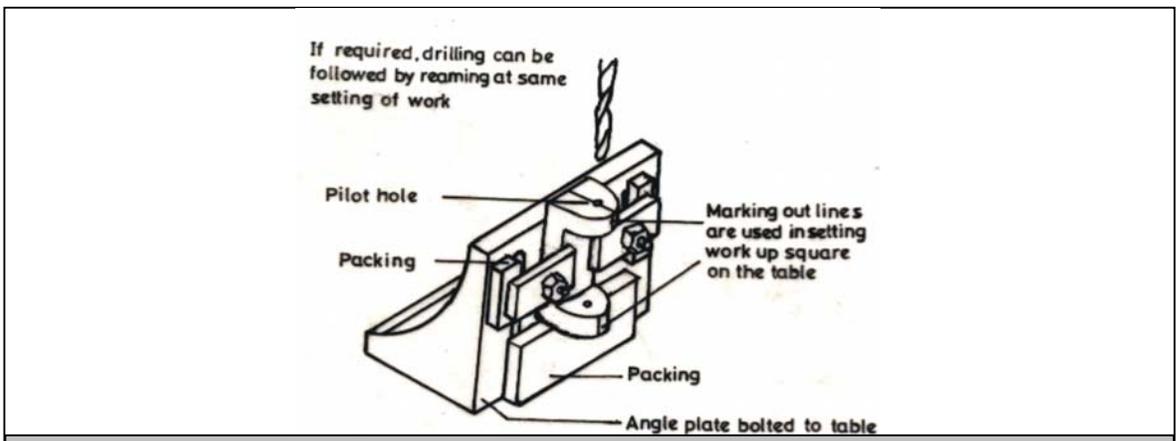


Fig. 10.20 Using an angle plate.

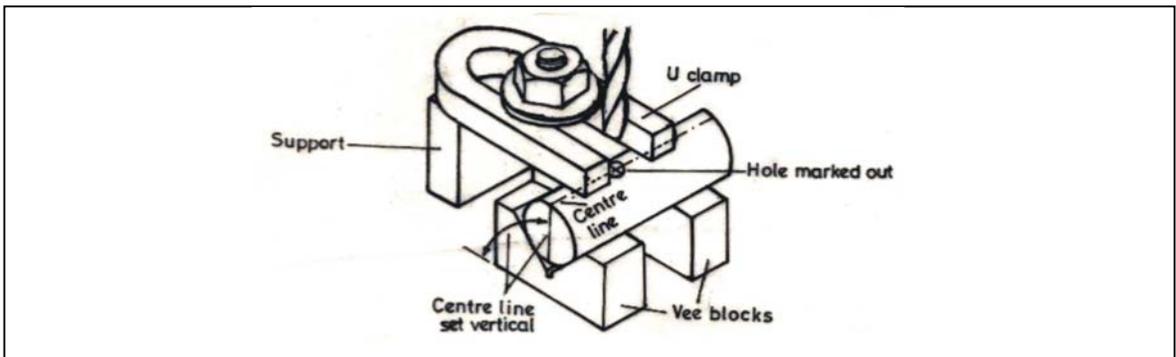


Fig. 10.21: Using Vee block and support.

**-Clamping Directly To The Machine table**

This method makes use of clamps, bolts and nuts. The table of a drilling machine is provided with slots to accommodate the clamps, bolts and nuts, which are used to clamp down the workpiece for drilling. This is shown in figure 10.22 below.

### Cutting Speed for Drilling

Cutting speed is the rate at which material is being removed. The cutting speed of the drilling depends on the circumferential speeds of the drill.

The formulae for calculating the cutting speed is given as:

$$CS = \frac{\pi DN}{1000}$$

Where CS=Cutting speed (in meters/min)

N=Spindle speed (rev/min) r.p.m.

D=Diameter

$$\pi = \frac{22}{7}$$

## TURNING MACHINES

The metal-cutting Lathe machines are considered as the primary machine tools. From historical perspective, Lathe machine constitutes the machine tool from which nearly all other machines tools have been developed. Among the drawings of machine tools of Leonardo da Vinci (1452 - 1519) the lathe with 'pole' drive with a treadle operating a crank was there. The crude lathes driven by water or animal power and which were based on Leonardo da Vinci were in existence in the year 1500's. The development of metal cutting lathe was developed around 18th century and Henry Maudslay constructed a lathe that had a leadscrew in 1810 in England.

The lathe machines now constitute the most useful and necessary machine used in machine shop or industry. They comprise nine types of machine tools which differ in the field of specialization, purpose, processing, capacities, size, construction arrangement and degree of their automation.

The main purpose of Lathe machine group is to machine accurately internal, external, face surfaces on solids and nut threads.

Lathe machines use single point cutting tools of various shapes and sizes used for turning operation. So also drills, core drills, reamers, taps and dies for cutting threads can also be used.

The classification of the Lathe machines is as follows;

- 1.General-Purpose Machines:** Centre or universal Lathes, turret or Capstian Lathes, facing lathes and precision Thread - cutting lathes.
- 2.High-Production Machines:** Multiple - tool lathes; semi - automatic and automatic lathes.
- 3.Single - Purpose and Specialised Lathes.**

### THE CENTRE LATHE MACHINE

Henry Maudslay, an English man, built the first practical screw - cutting lathe. The machine was considered to be slow then, but the basic principle of Maudslay's lathe (screw - cutting lathe) is still the heart of industrial manufacturing, most especially in the tool rooms.

The Centre Lathe machine is referred to as the father of all machines, and is considered to be the most important machine-shop tool, and most versatile machine of the lathe group.

Centre or Universal Lathe machine can be sub-divide into;

The modern centre lathe is used for;

- (i)producing flat surfaces by turning;
- (ii)producing cylindrical shapes by turning;
- iii)drilling and boring holes;
- iv)the production of external and internal round shape other than plain cylinders;
- (v)internal and external screw threads cutting;

(vi) Special machining operations other than turning notably, milling involving the use of special attachment.

The linear accuracy of the machined component/work done on the centre lathe depends solely on the skill and experience of the turners or machinists. Therefore, a highly skilled, craftsman (Machinists, or Turners) are required for the production of accurate, well-finished work without wasting time in the removal, planning and setting of the job on the lathe.

Centre Lathe machine can be specified using the suitable dimensions for a particular job based on;

- The maximum distance between the head stock and tailstock centres, usually termed the length or distance between centres
- The largest diameter of work which will revolve without fouling the bed, termed the swing over bed.
- The largest diameter of work which will revolve without fouling the tool carriage, usually referred to as swing over carriage.
- The diameter of the hole through the lathe spindle, very important when bar-material is to be turned.
- length of bed.

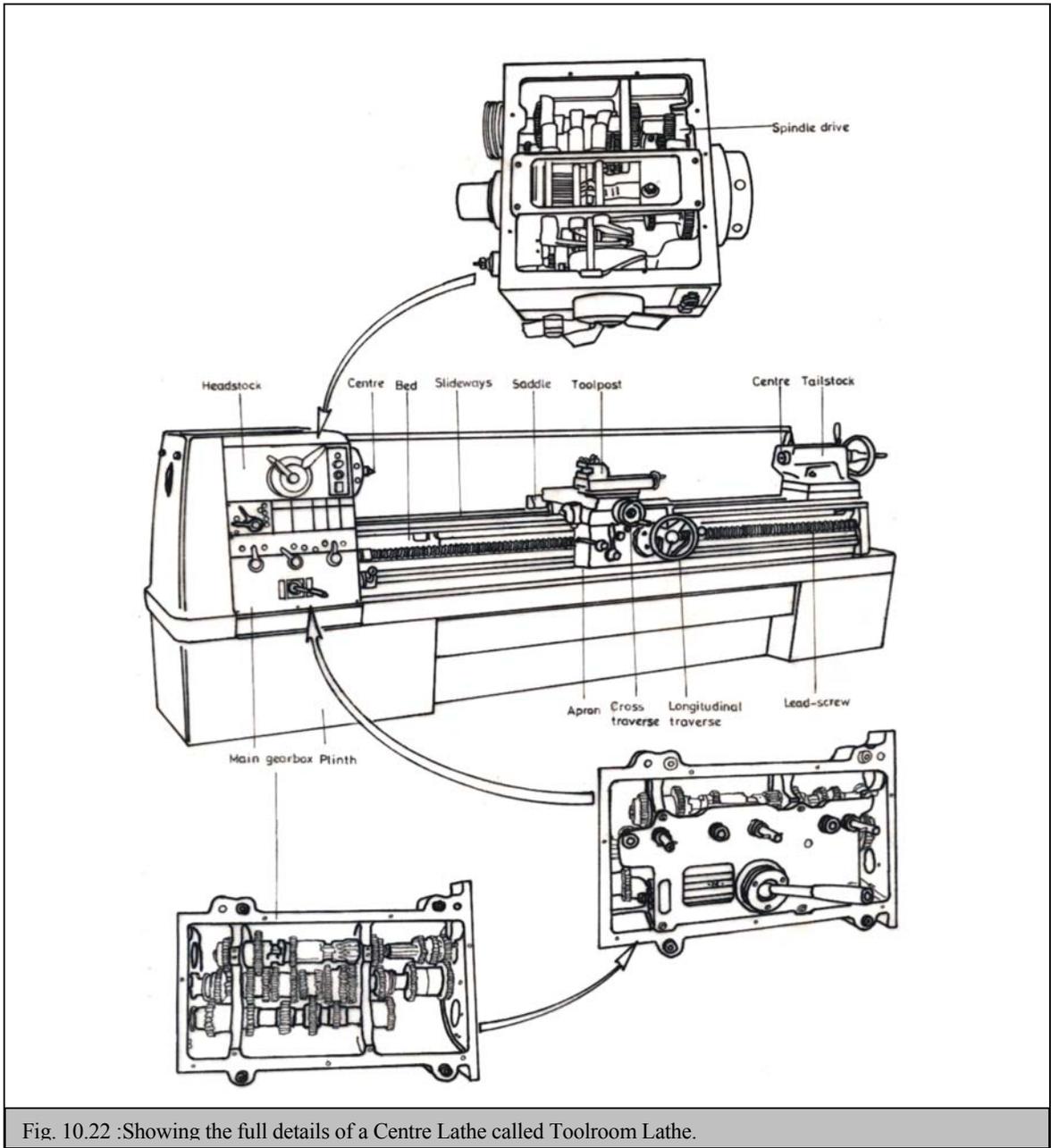


Fig. 10.22 :Showing the full details of a Centre Lathe called Toolroom Lathe.

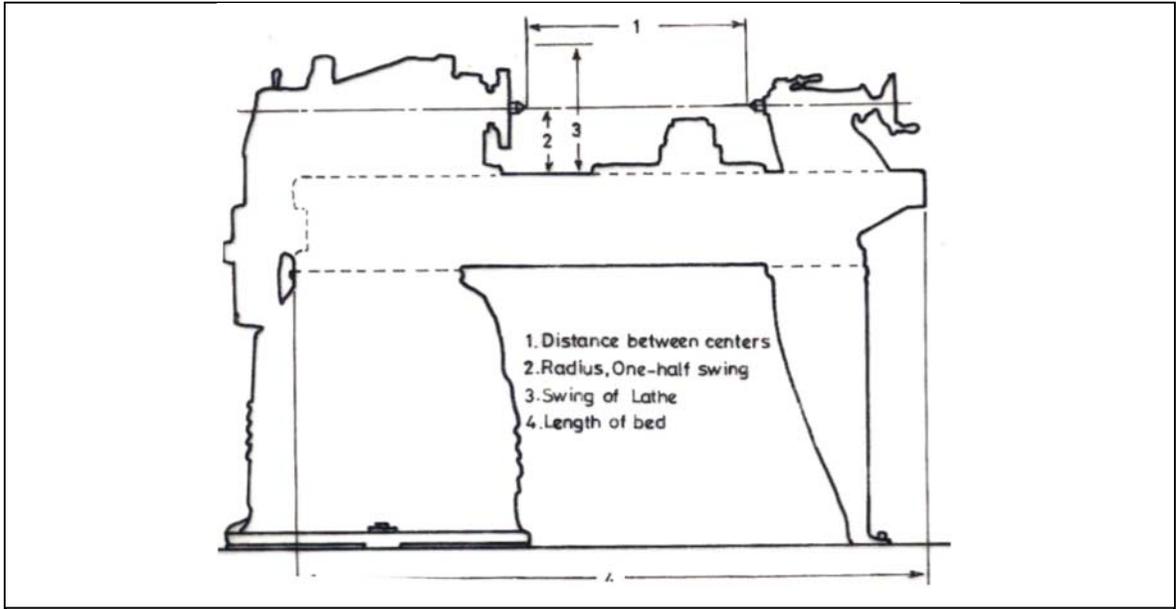


Fig. 10.23: The specification of the Centre Lathe.

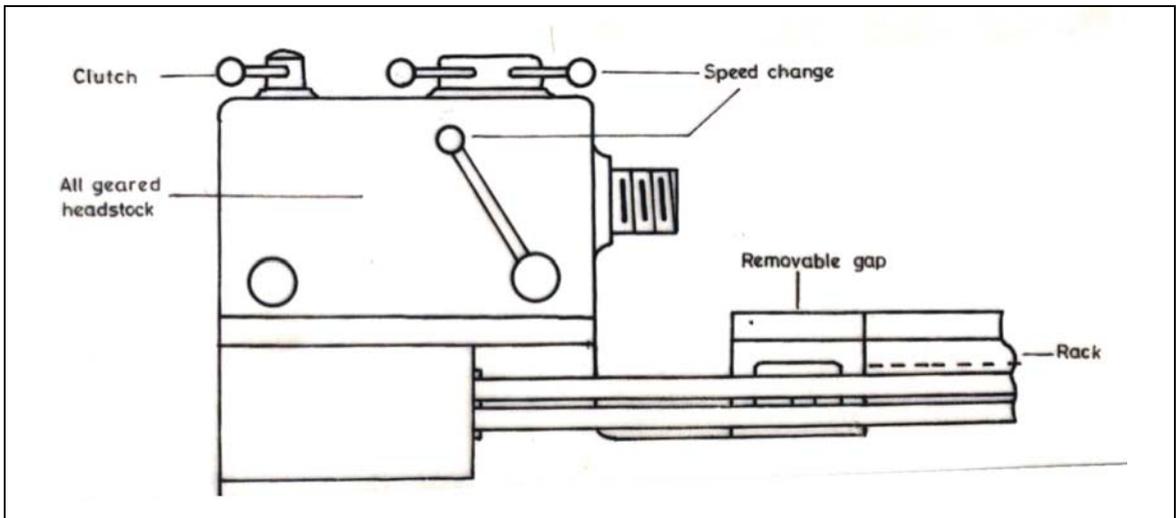


Fig. 10.24: The Features of the Headstock

iii) Inverted Vee and Flat guides.

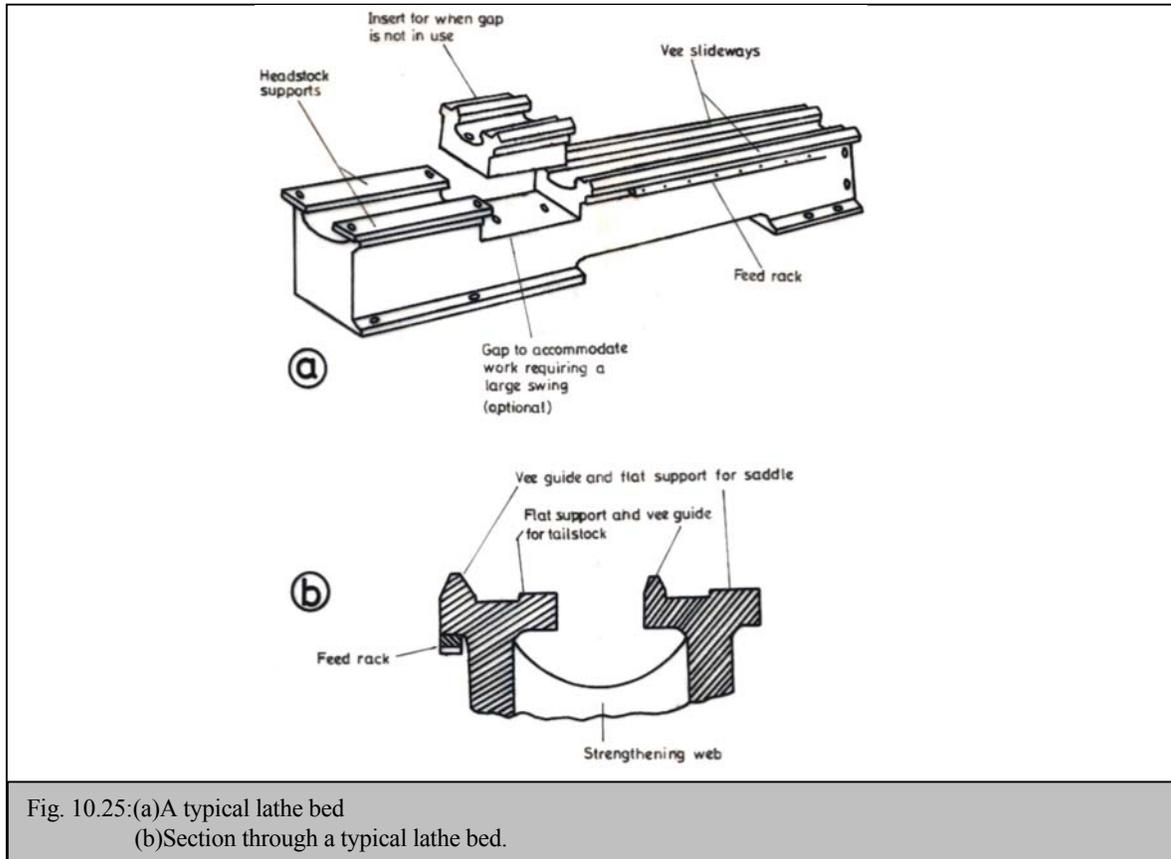


Fig. 10.25:(a)A typical lathe bed  
(b)Section through a typical lathe bed.

Many lathe machines are provided with a short gap in the bed (Fig. 10.25 (a)). This is in front of the headstock (fig. 10.25). It enables the lathe to accommodate large wheels and pulleys. Removable gap-piece is provided in large machines, while smaller machine is usually left open permanently.

### Cutting Tool Holders

Centre Lathe cutting tools are in a tool posts. The tool is held rigidly in position ready to cut. The tool post is mounted on the compound slide.

The toolposts are of various designs, but the most common ones are illustrated in figure 10.29..

Single or simple Tool posts are shown in fig. 10.29 above. In both the diagram (a) and (b) the holder is capable of carrying only one tool at a time. The tool is held in position by the use of bolt and nut. It must be capable of being locked firmly into the desired position.

Fig. 10.29(a) is popular for small to medium sized lathes and figure 10.29(b) is used on heavier lathe machines, when heavy cut and a bigger tool is to be held in position.

The American Tool post is shown in fig. 10.30 below. It is widely used on small lathe machines. It has the advantages of setting the tools quickly to the holder. When setting the tool, the adjustment for the height is done by swiveling the boat or rocker.

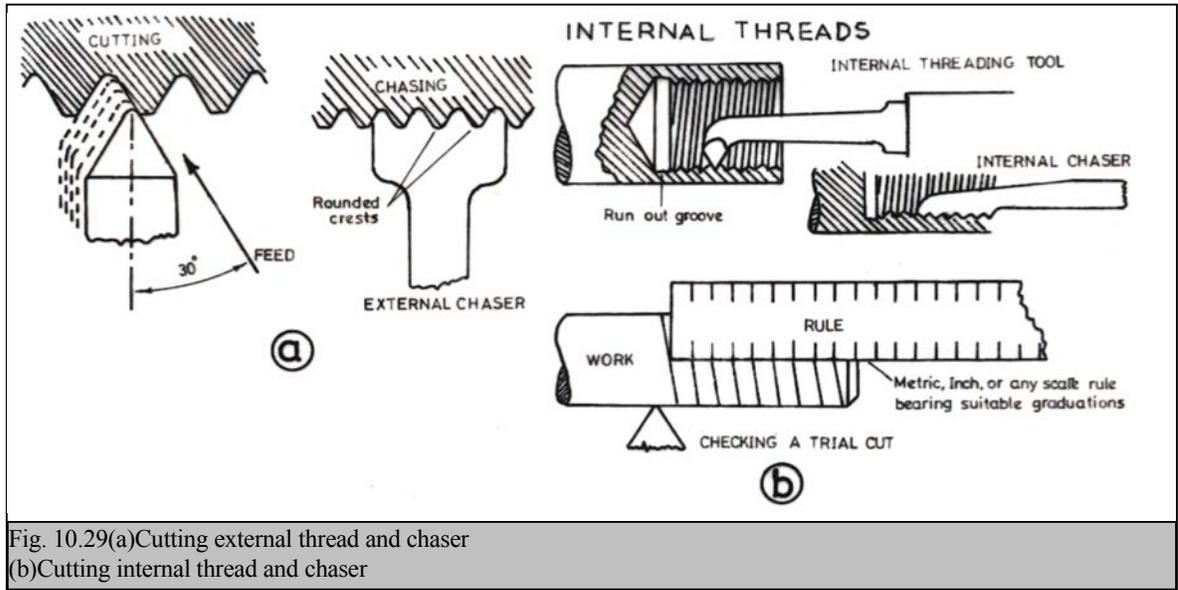


Fig. 10.29(a)Cutting external thread and chaser  
(b)Cutting internal thread and chaser

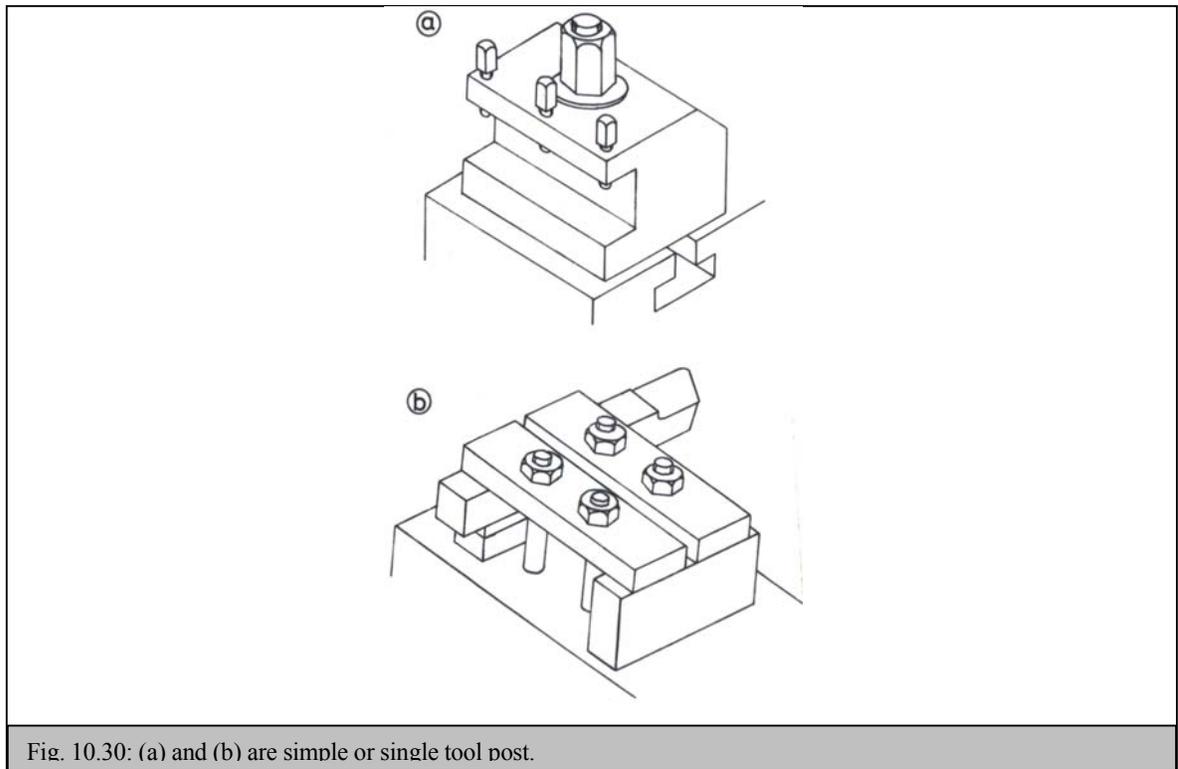
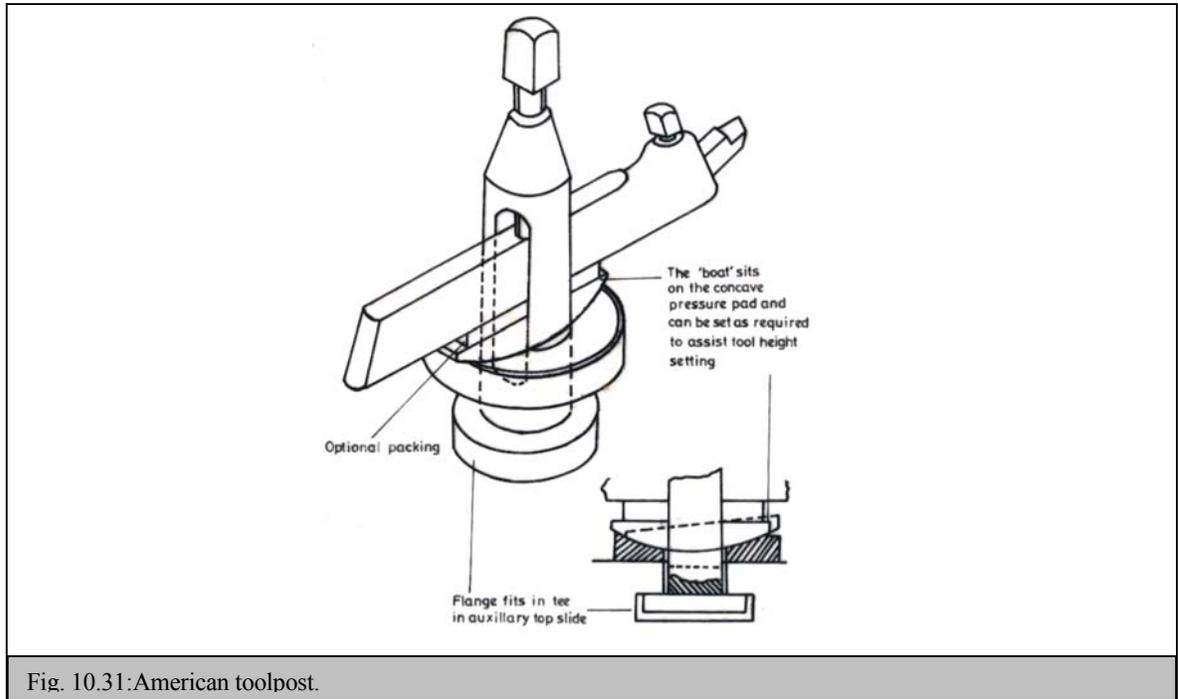


Fig. 10.30: (a) and (b) are simple or single tool post.

**(ii)The American Tool Post**



**(iii)The Four Way Tool Post**

The four way tool post is shown in fig. 10.31. This is similar in principle to fig. 10.30(a) one way tool post described earlier. The difference is that this type is capable of holding four tools at the same time. It is brought to work by rotating the work toolpost and the appropriate tool is used. It has the advantages of saving time in the setting or changing of tools for different operations on the lathe.

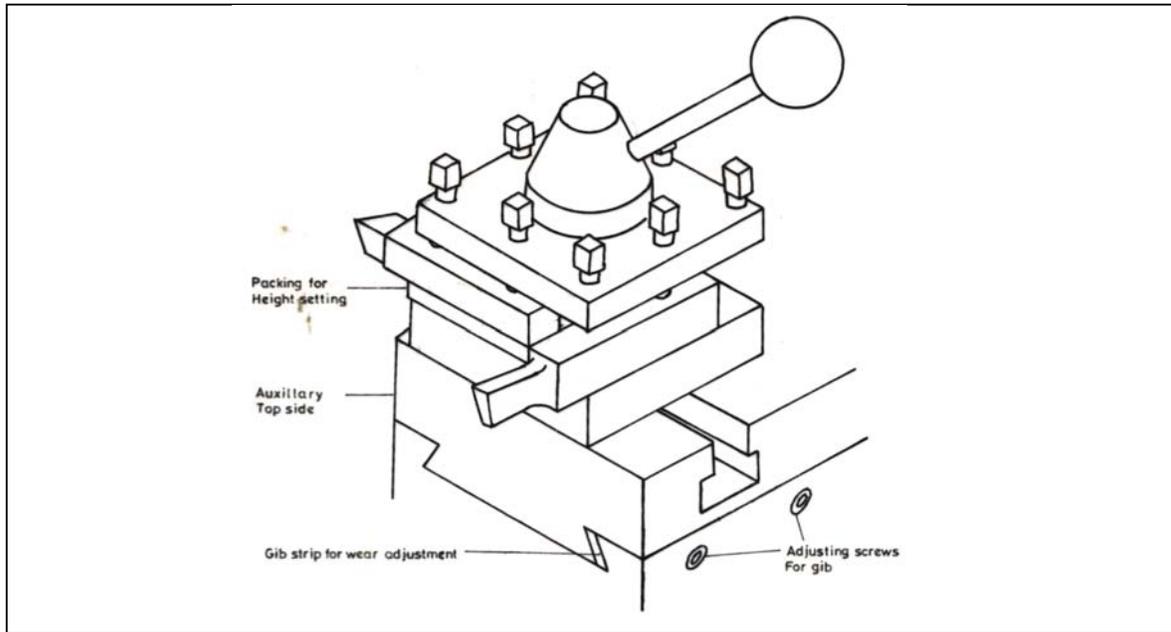


Fig. 10.32:Four way Tool Post.

**(iv)A 'Quick - change' Tool Post**

A "Quick-change" toolpost is shown in fig. 10.33. It derives its name from the ability to change the tool in few seconds. Unlike the other tool post that requires packings, the tool does not require any packing, individual tool holders are adjusted to the required height. No tool setting to height, as the tool is removed and replaced, it will automatically resume the correct tool height.

A "Quick-change" tool post consists of a specially shaped substantial pillar which holds different types of tools.

Each of the tools is held in the tool holder.

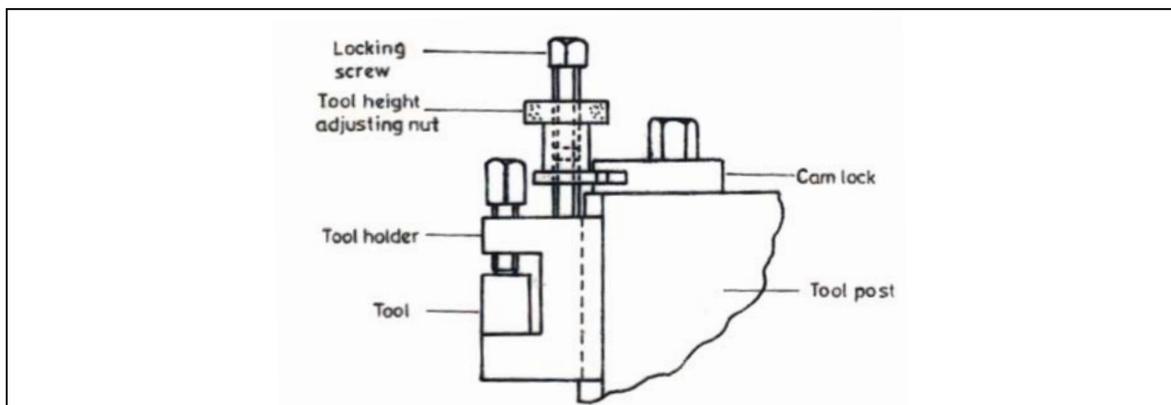


Fig. 10.33:A "Quick-change" Toolpost

**Work-Holding Devices**

The work holding devices used on Centre Lathe machine for turning operations are:

- (i)Chucks-(a)Three-jaw self-centering chuck
- (b)Four-jaw independent chuck
- (ii)Driving dogs or carriers
- iii)Faceplates
- (iv)Catch-plates

(v)Mandrel

(vi)Collets

Enumerating each work-holding devices one by one;

**(i)Chucks**

Centre Lathe chucks are used to hold work for turning or machining operations on the centre lathe machines. There are two main types of chucks used namely;

**(a)Three-Jaw "Self Centering Chuck"**

As the name, the three jaw chuck has three jaws which is capable of moving in or outwards by the use of hand key which is put on one of the three square slot provided in the body of the chuck.

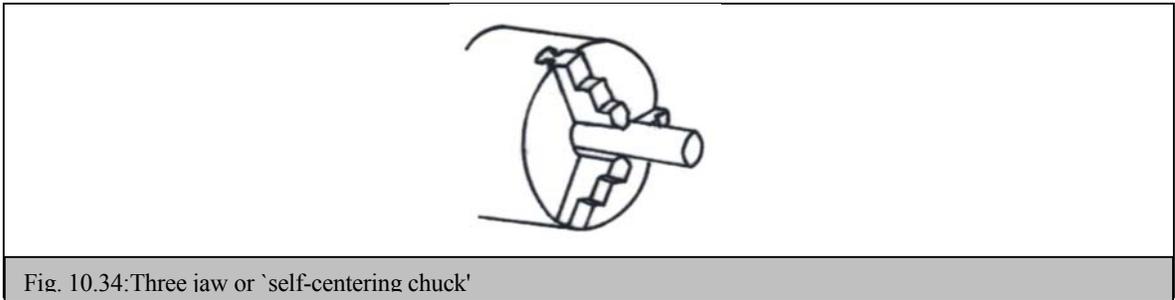


Fig. 10.34:Three jaw or 'self-centering chuck'

Three-jaw or self centering chuck has the advantages of setting up job quickly than its counterparts four-jaw or independent chucks.

The gripping efficiency of the chuck is much less than that of four jaw chucks, therefore, it is not used where extreme accuracy is required.

**(b)Four-Jaw Independent chuck**

Four-jaw chuck is also known as independent chuck, that is the chuck has four jaws and the jaws can be set independently. The jaws are reversible. The square slot provided on the body of the chuck takes the chuck key which is capable of moving in and out of the jaw through the use of threaded jaw which fits into the stud.

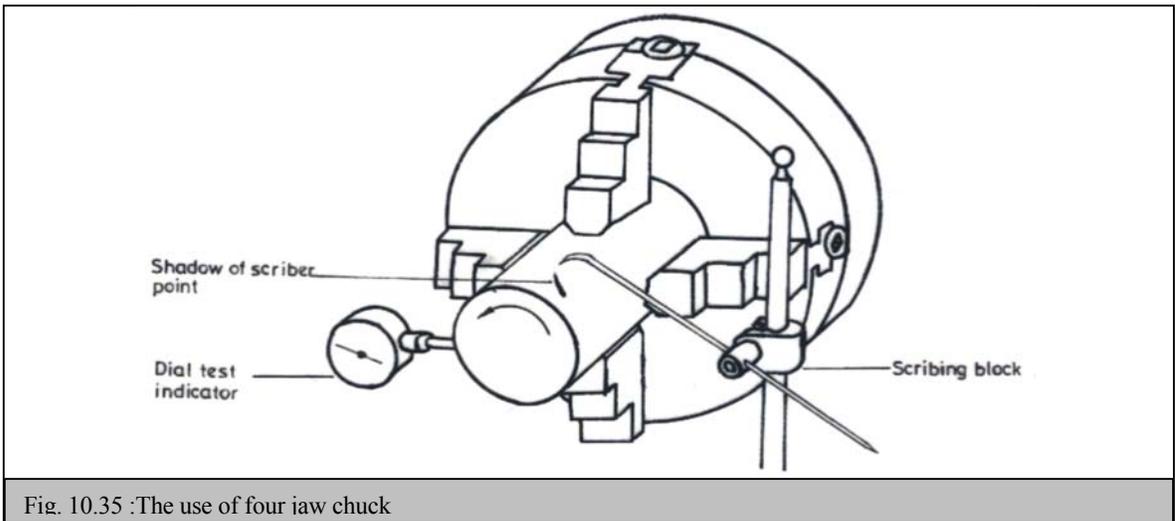


Fig. 10.35 :The use of four jaw chuck

**(ii)Driving Dogs or Carriers**

This is available in a range of sizes and bolts to the workpieces as shown in fig. 121 which is used to transmit motion from driving plate through driving pin to the workpiece turned between centres on the lathe machine.

The main types of driving devices are dogs, yokes, driving faceplates and driver chucks as shown in fig. 10.36 below.

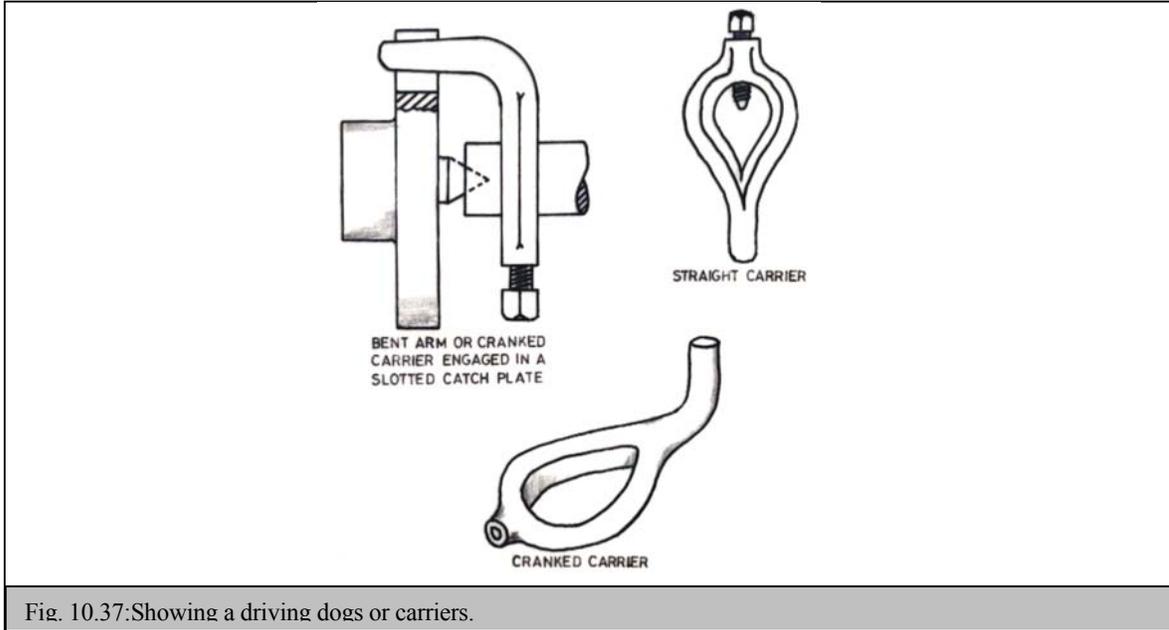


Fig. 10.37: Showing a driving dogs or carriers.

**(iii) Face plate**

The Faceplate is an accessory used for holding work which cannot be held conveniently in a chuck, such as irregularly shaped works and large diameter works. The face plate is a circular cast iron plate, and slots are provided in the plate to accommodate bolts for clamping the work as shown in fig. 10.38

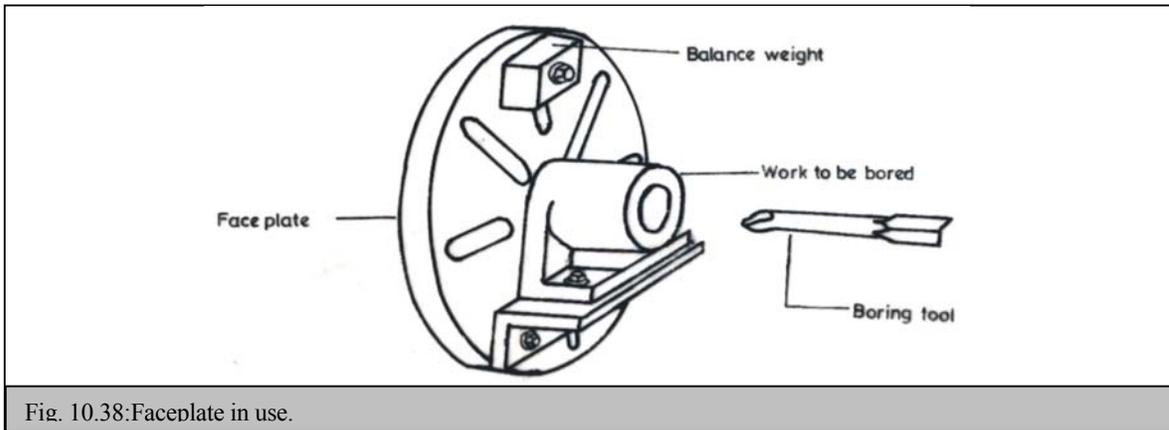


Fig. 10.38: Faceplate in use.

**(iv) Catch-Plate**

Catch-plate is usually used to drive work between centres by mounting it on the lathe spindle, and a driving pin engaging with a 'carrier' (or 'dog') which is screwed on to the end of the work thereby causing the work between centres to rotate as shown in fig. 10.39.

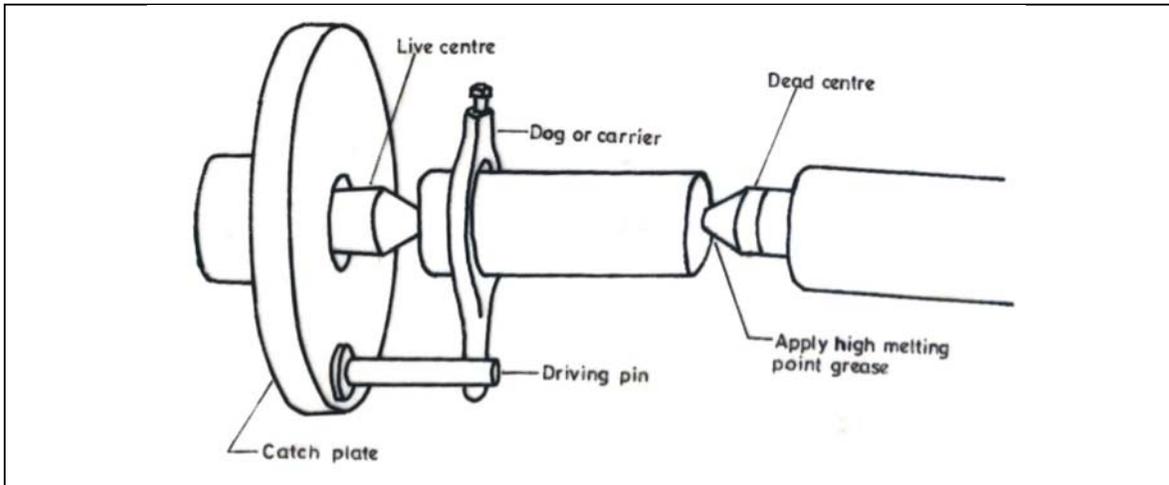


Fig. 10.39: Catch - Plate in use.

**(v) Mandrels**

Mandrels are cylindrical work-holding devices having the additional advantages of precision location. This is provided by accurate centres at both ends. It is used for completing works which have been bored and partly turned in the chuck.

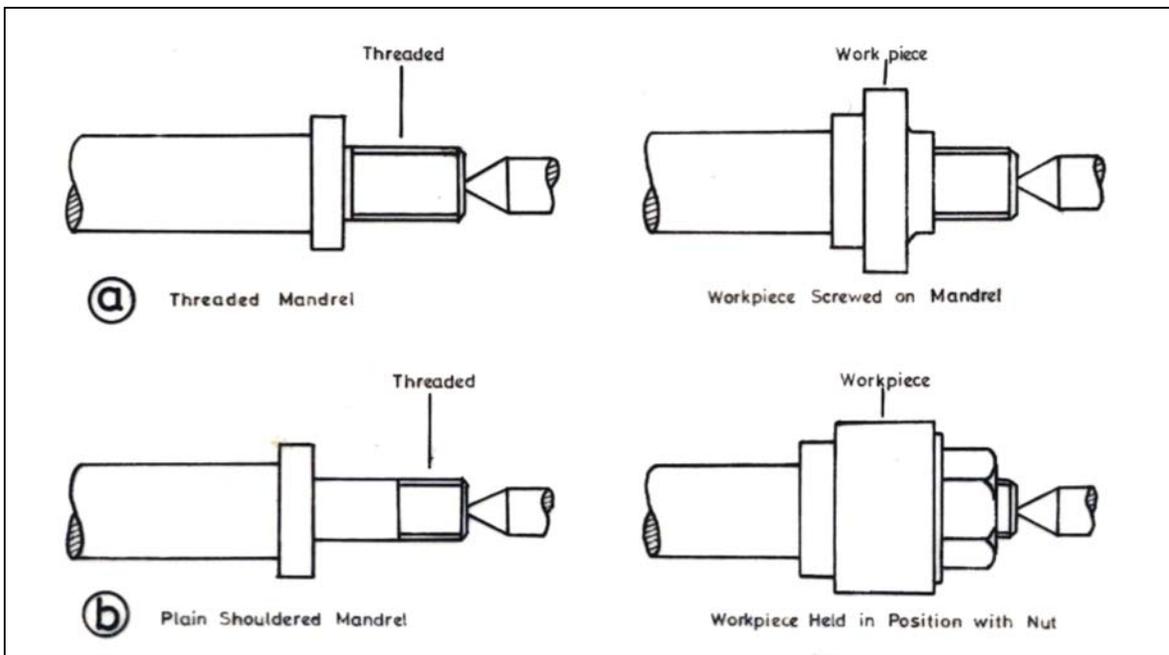


Fig. 10.40(a) Threaded mandrel

(b) Plain shouldered mandrel

**(vi) Collets**

Collets are used for holding small work up to about 16 mm diameter. The use of collets is materialised for mass production because of the unsatisfactory efficiency of 3 Or 4 jaw chuck. The problem can be as a result of frequent setting each time it was used, the jaws marking the surface of the workpiece, and the inability of the tool moving close to the chuck. The collet chuck overcomes these disadvantages and permitting high precision work involving mutual concentricity between two steps to be achieved.

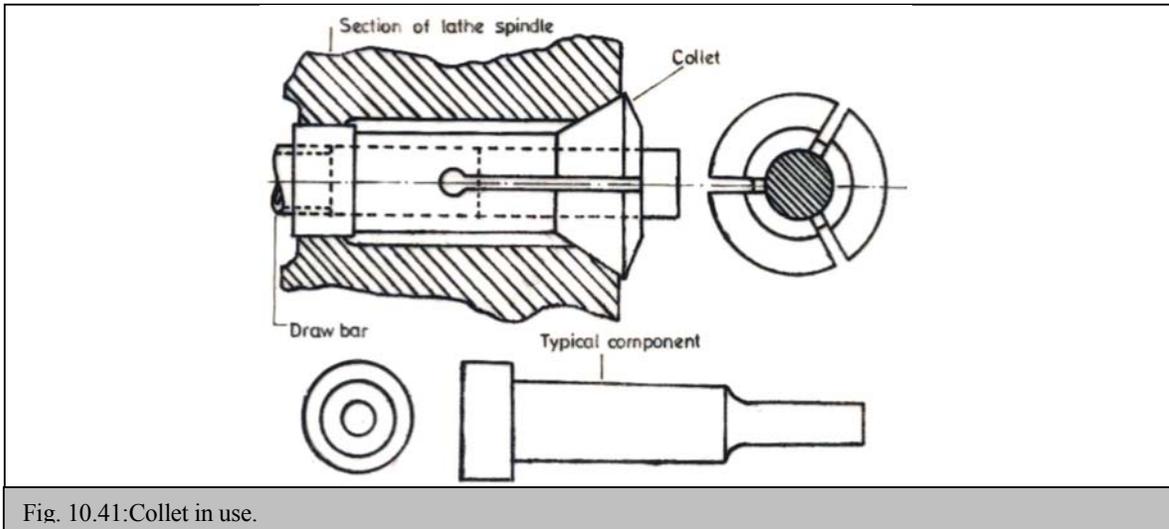


Fig. 10.41: Collet in use.

#### 10.2.1.4 Work - Holding Supporting Devices

The work - holding supporting devices use on Centre Lathe machine for turning operations are;

##### (i)Centres

Centres are made to fit to the taper sockets of the headstock and tailstock are machined having morse taper, and the point which fits the centre hole in the work is generally made to an angle of  $60^\circ$  and sometimes  $75^\circ$  or  $90^\circ$  for heavy work. Lathe Centres are usually made of carbon tool steel which is hardened with little or no temper. Lathe centres are classified as follows:

**Headstock Centres:** The centres usually used on the headstock are known as standard (live), extensible, driving and reverse centres. The standard centres are employed when press-fit pluge with standard holes into the centre hole of the work.

Extensible centres usually used with driving chucks are made use of when an exact distance must be maintained from shoulders to grooves and to the end face of the work.

Driving headstock centre with a pyramid point are used to locate the work and to drive it at the same time.

Reverse centres are used to machine small workpiece in which a centre hole cannot be made. The external centre made on such work, enter hole in the reverse centre shown in fig. 10.42 below;

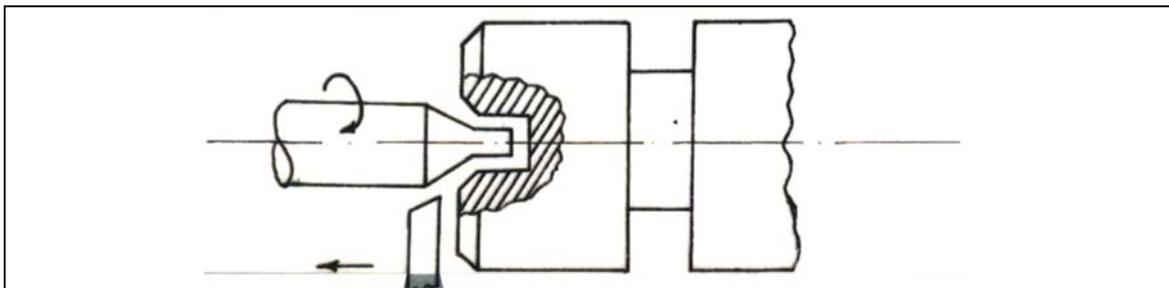


Fig. 10.42 Reverse Centre

**Tailstock Centres:** The centres usually used on the tailstock are known as;

-Dead Centres; standard and half centres

-Ball bearing centres; sharp-pointed and special centres.

Standard centres which can be located in the tailstock or headstock has the difference that the one located at the tailstock is called dead centre (unable to rotate with work), and the one located at the headstock is called live centre (it can rotate).

Half centres are used in the tailstock to allow the tool to face the edge of the centre hole that is mounted between centres, or when work of smaller diameter requires a space to enable a tool to be fed into the work.

Ball and roller bearing centres are used in multiple-tool lathes and for high-velocity machining in centre lathes. It has the advantages of reducing the wear on the point of the centre, as well as in the centre hole of the work. It can also be used for taper turning using the "set-over tailstock" method.

**(ii)Steadies**

Long and slender work, even when supported at both ends by the live or dead centres or held in the chucks, tends to bend under the cutting pressures of the tool. Therefore, for supporting long, slender work against the vibrations, deflection and pressure of the cut, a steady is used.

There are two types in common use, they are:

**Travelling steady:** Travelling steady is bolted or attached to the cross slide or carriage of the lathe and travels along with the tool. It supports the workpiece from behind and above. It is also used in supporting slender bars against the thrust of the cut.

**Fixed Steady:** The fixed steady consists of three adjustable jaws supported in a cast iron frame, and is clamped to the bed of the lathe and support the end of long shafts during facing, milling and boring operations. The point at which the jaw makes contact with the work should be greased always.

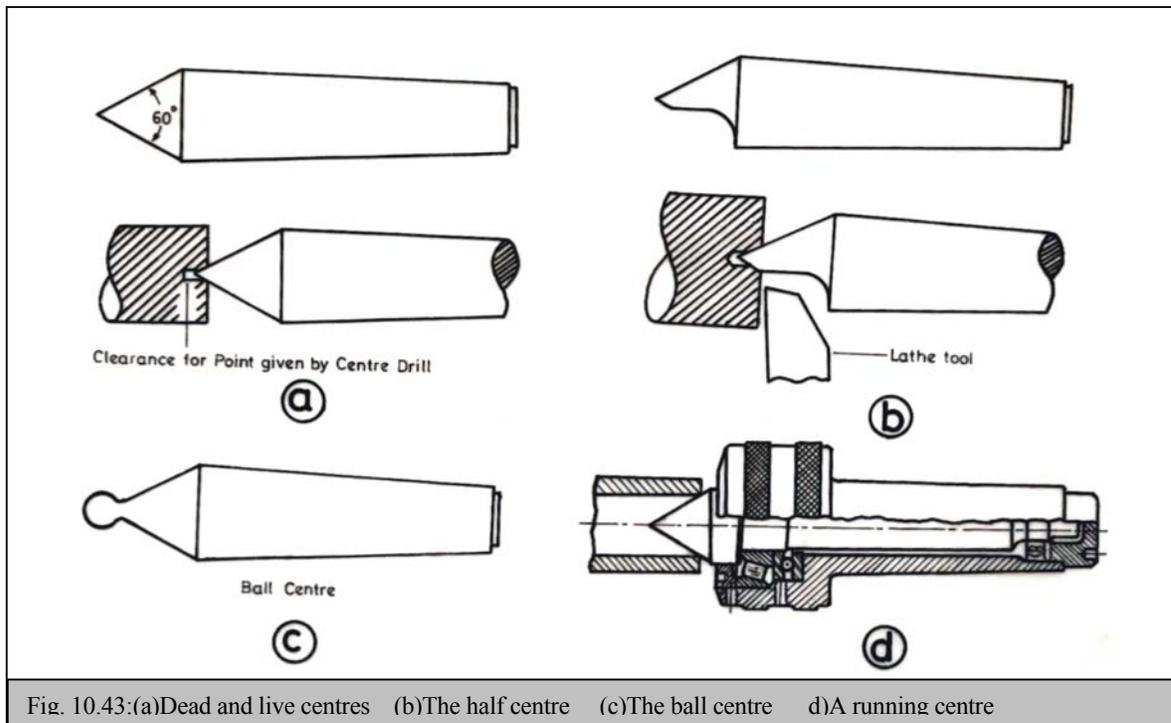


Fig. 10.43:(a)Dead and live centres (b)The half centre (c)The ball centre d)A running centre

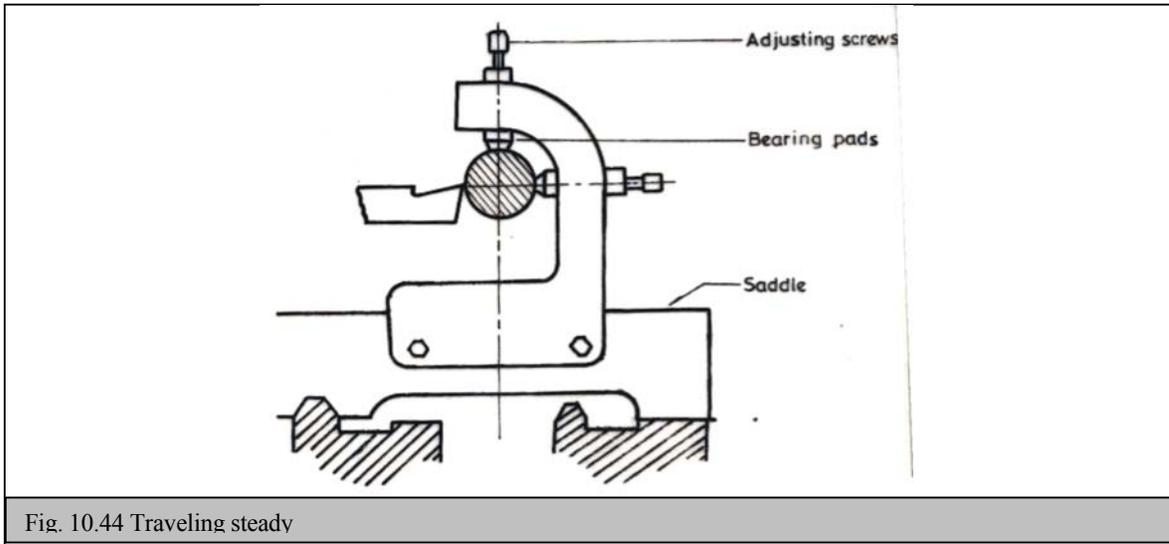


Fig. 10.44 Traveling steady

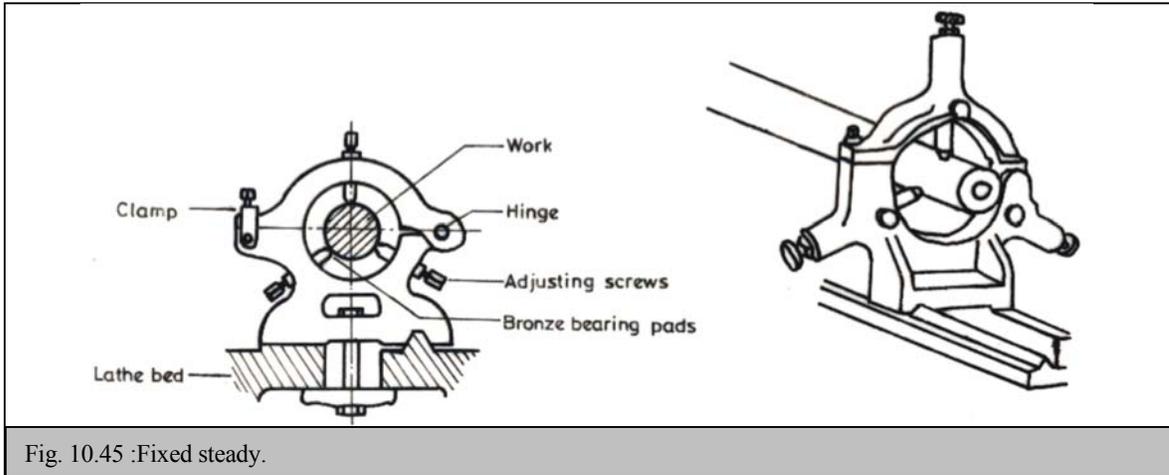


Fig. 10.45 :Fixed steady.

### Types of Turning Tools

Lathe turning tools have basically similar cutting edges, but the precise geometry of each tool-point is determined by various factors which ranges from tool material and the work piece material to be dealt with.

Lathe tool can be made from any of the following materials;

- (i) **Plain Carbon Steel** - Capable of loosing hardness over prolong use.
- (ii) **High Speed Steel** - It possesses the property of 'red-hardness' capable of retaining property and hardness at red heat.
- iii) **Stellite** - Used as a tipped tool at very high speed. It retains its hard cutting edge becoming tougher even at red heat.
- (iv) **Cemented Carbide** - Almost as hard as diamond but very brittle and has a low tensile strength. Used in form of tipped tool.
- (v) **Ceramics** - Made from sintered aluminium oxide. Used as a tipped tool. Highly suitable where very high cutting speeds and where there is no intermittent cutting is desirable.
- (vi) **Diamond** - Used in form of tipped for high grade machining of hard metals and plastics which is capable of making the High speed steel tool blunt.

The lathe turning tool forms are of;

**Solid:** This is one piece tools which are made of one single materials.

**Butt-Brazed:**

It can also butt-weld. These types of tool are made by brazing or welding a piece of High speed steel to the tip or front of high tensile steel which serves as a shank.

**Tipped:**

This type of tool has a tip of comented carbride, diamond etc. brazed or welded to a blank of high tensile steel which serves as shank.

**Tool Bits:**

This type of tool fits into special holder that grips the tool at an angle  $15^\circ$ . The purpose of the angle is to provide for easy height adjustment.

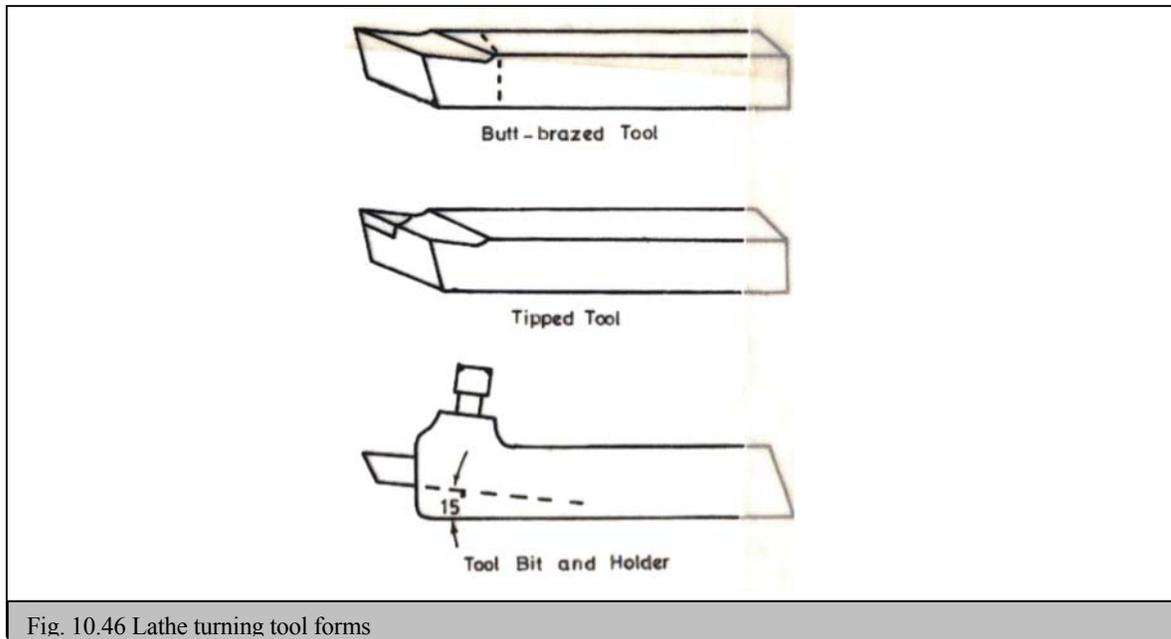


Fig. 10.46 Lathe turning tool forms

## Inspection and Quality Control

### Inspection

**Inspection** means checking the characteristics of a product to ensure that conformity to a set of specifications is met. Sometimes it means checking 100% of a batch of product; sometimes it means checking only some samples (in that latter case, it is exactly the same as "statistical quality control". Inspection involves measuring, examining, and testing products, process and services against specified requirements to determine conformity.

The use of inspection has been evident throughout the history of organised production. In the late Middle Ages, special measures were taken to inspect the work of apprentices and journeymen in order to guard the Guild against claims of makeshift or shoddy work.

During the early years of manufacturing, inspection was used to decide whether a worker's job or a product met the requirements; therefore, acceptable. It was not done in a systematic way, but worked well when the volume of production was reasonably low. However, as organisations became larger, the need for more effective operations became apparent.

In 1911, Frederick W. Taylor helped to satisfy this need. He published 'The Principles of Scientific Management' which provided a framework for the effective use of people in industrial organisations. One of Taylor's concepts was clearly defined tasks performed under standard conditions. Inspection was one of these tasks and

- was intended to ensure that no faulty product left the factory or workshop;
- focuses on the product and the detection of problems in the product;
- involves testing every item to ensure that it complies with product specifications;
- is carried out at the end of the production process; and relies on specially trained inspectors.

This movement led to the emergence of a separate inspection department. An important new idea that emerged from this new department was defect prevention, which led to quality control.

Inspection still has an important role in modern quality practices. However, it is no longer seen as the answer to all quality problems. Rather, it is one tool within a wider array.

### Quality control

**Quality control** usually means only checking the conformity of products already made. It comprises inspection and other tests such as lab tests. Some people use quality control to designate some more upstream activities that aim at preventing quality issues (usually these activities are called "quality assurance").

Quality control, can also be defined as a process by which entities review the quality of all factors involved in production. This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well managed processes, performance and integrity criteria, and identification of records
2. Competence, such as knowledge, skills, experience, and qualifications
3. Soft elements, such as personnel integrity, confidence, organizational culture, motivation, team spirit, and quality relationships.
4. Quality control is the activities or function necessary to make the company fulfill its quality objectives.
5. The terms quality management, quality control, and quality assurance are often used interchangeably. No matter the use, it is the continual evaluation of the effectiveness of the

total cost quality system. ANSI/ASQC standard X – 1.15 (available from American Society for quality Control) has the elements of total quality control to be:

- i. Policy, planning and administration,
- ii. Product design and design change control
- iii. Control of purchased Material
- iv. Users contact and field performance
- v. Corrective action
- vi. Production quality control
- vii. Employee selection, travelling and motivation.

Quality has no rigid definition in that a product which is of high quality in a given circumstances may be of poor quality in another situation. So it can be said that quality is the acceptance at a point in time of fitness or purpose.

In determining the quality of a product the need of a consumer and his belief in this need must be employed. Quality of a product is a managerial decision and both external environment and material resources are considered.

The quality policy must;

- i. Identify customers needs and his perception of the needs
- ii. Asses total ability of the organization to produce the product economically
- iii. Ensure that the quality is understood at all levels
- iv. Obtain feedback of information from the market
- v. Monitor performance from the manufacturing unit

Quality begins with;

- i. The design of a product in accordance with customers task and standards
- ii. The use of suitable or appropriate materials
- iii. The selection of appropriate manufacturing process
- iv. The performance of the manufacturing operations
- v. The inspection of the product to check the conformance with the specifications.

The customers used the product, and feedback about the product from the customers is needed to check if the product is in accordance with the specification

Quality can be used or is referred to in three ways;

- i. Quality in design: Degree of achievements of purpose by the design itself.
- ii. Quality of conformance with specifications: faithfulness with which products agrees with design (customer's satisfaction).
- iii. Quality of performance: This is a performance evaluation of the product in use.

Quality control is a staff function, which is concerned with the prevention of defects in manufacturing, that is the process of achieving good quality for the first time and not have to be rejected.

Variation in all operating systems necessitates the qualities analysis and quality control. he need for the analysis and control is of two folds:

- i. Variation (Non-Uniformity), there is no two units of outputs alike.
- ii. The production and use of products and services are most economical when uniform quality products are produced.

The higher the quality level of a product, the higher is cost to manufacture it

The quality of the outputs is at risk if any of these three aspects is deficient in any way.

Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place. For contract work,

particularly work awarded by government agencies, quality control issues are among the top reasons for not renewing a contract.

### **Total quality control**

"Total quality control", also called total quality management, is an approach that extends beyond ordinary statistical quality control techniques and quality improvement methods. It implies a complete overview and re-evaluation of the specification of a product, rather than just considering a more limited set of changeable features within an existing product. If the original specification does not reflect the correct quality requirements, quality cannot be inspected or manufactured into the product. For instance, the design of a pressure vessel should include not only the material and dimensions, but also operating, environmental, safety, reliability and maintainability requirements, and documentation of findings about these requirements.

The term 'total quality' was used for the first time in a paper by Feigenbaum at the first international conference on quality control in Tokyo in 1969. The term referred to wider issues within an organisation.

Ishikawa also discussed 'total quality control' in Japan, which is different from the western idea of total quality. According to his explanation, it means 'company-wide quality control' that involves all employees, from top management to the workers, in quality control.

### **Total Quality Management**

In the 1980s to the 1990s, a new phase of quality control and management began. This became known as Total Quality Management (TQM). Having observed Japan's success of employing quality issues, western companies started to introduce their own quality initiatives. TQM, developed as a catchall phrase for the broad spectrum of quality-focused strategies, programmes and techniques during this period, became the centre of focus for the western quality movement.

A typical definition of TQM includes phrases such as: customer focus, the involvement of all employees, continuous improvement and the integration of quality management into the total organisation. Although the definitions were all similar, there was confusion. It was not clear what sort of practices, policies, and activities needed to be implemented to fit the TQM definition.

### **History of Quality**

The roots of Total Quality Management (TQM) can be traced back to early 1920s when statistical theory was first applied to product quality control. This concept was further developed in Japan in the 40s led by Americans, such as Deming, Juran and Feigenbaum. The focus widened from quality of products to quality of all issues within an organisation – the start of TQM.

### **Quality Control and Statistical Theory**

Quality Control was introduced to detect and fix problems along the production line to prevent the production of faulty products. Statistical theory played an important role in this area. In the 1920s, Dr W. Shewhart developed the application of statistical methods to the management of quality. He made the first modern control chart and demonstrated that variation in the production process leads to variation in product. Therefore, eliminating variation in the process leads to a good standard of end products.

**Statistical Quality Control:**

- focuses on product and the detection and control of quality problems;
- involves testing samples and statistically infers compliance of all products;
- is carried out at stages through the production process; and
- relies on trained production personnel and quality control professionals.

All manufacturing processes are subject to random variation. Some of the measurement of this variation is looked at from the statistical approach thus:

**Tally Chart**

Tally Chart is the most convenient way to record the information

This tally chart can be presented as a graph of frequency against size.

The frequency polygon is a typical representation of a manufacturing process where size is subject to random variation.

**Calculation of Variance and Standard Deviation**

The sample variance  $S^2$  of  $n$  observations  $x_1, x_2, \dots, X_n$  is given as

$$S^2 = \frac{(x-x_1)^2 + (x-x_2)^2 + \dots + (x-x_n)^2}{n-1}$$
$$= \frac{\sum (x-x_i)^2}{n-1}$$

For population variance

$$\Delta^2 = \frac{\sum (x-x_i)^2}{N}$$

The Standard Deviation ( $s$ ) is given as