LECTURE HANDOUTS

L - 01

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Brief introduction to CAD and CAM – Manufacturing Planning

Introduction : (Maximum 5 sentences)
CAD/CAM combination allows the transfer of information from the design stage into the stage of planning for the manufacture of a product without the need to re-enter the data on part geometry manually. Database developed during CAD is stored.

Prerequisite knowledge for Complete understanding and learning of Topic:
Design, Manufacturing, Process planning,

Detailed content of the Lecture:

- Computer aided design is an approach to product and process design that utilizes the power of a computer. CAD is defined as any design activity that involves the effective use of the computer to create, modify or document an engineering design

CAD Hardware and Software

- CAD Hardware: CAD hardware generally includes the computer, one or more graphical display terminals, key board and other peripheral equipment's like electronic plotter, printer, card reader
- **System Software:** used to perform/control the operation of the computer. These are responsible for making hardware to work and interact
- **Application Software**: Known as application program, are used for general or customized / specialized problems (AutoCAD, CATIA, ANSYS, Pro-E)

Reasons for Implementing CAD

- To increase the productivity of the designer*:* The designer can visualize quickly the product and its component, sub-assemblies and parts. This reduces the time required for analysis and documentation of the design
- To improve the quality of design: Design alterations can be done quickly without error
- To improve communications: CAD provides better documentation of the design, drawing error with greater legibility
- To create a database for engineering.: Design database consists of product geometries and dimensions , bill of materials which are essential input for manufacturing of the product

Benefits of CAD

- Increased design productivity: It helps in increased design productivity by reducing the time for developing conceptual design, analysis and drafting

- Shorter lead time : the designer to prepare a set of finished set of drawing and documentation in a relatively short time
- Flexibility in design: It is easy to change or manipulate the geometric shapes and sizes and other specifications according to customer specific requirements
- Improved design analysis: helps to optimize the design with the use of analysis software
- Fewer design error : CAD systems have in built capability for avoiding errors
- Greater accuracy in design calculation : CAD's high level of dimensional control
- Standardization of design, drafting and documentation procedures*:* Single database and operating system used in CAD provides a common basis
- Easier creation and correction of engineering drawings: any type of view can be generated quickly and efficiently

Computer Aided Manufacturing (CAM)

- CAM is defined as an effective use of computers and computer technology in the planning management, and control of the manufacturing function

Applications

1. Manufacturing planning
2. Manufacturing control

Manufacturing Planning

- CAM is those in which computers are used indirectly to support the production function, but there is no direct connection between the computer and the process.

Manufacturing Control

- Manufacturing control is concerned with managing and controlling the physical operations in the factory.

Some of the manufacturing control are

- Process monitoring and control
- Quality
- Shop floor control
- Inventory Control
- Just – in time production system

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=vO1lc75jtiM

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 1-4

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LECTURE HANDOUTS

L - 02

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Manufacturing control- Introduction to CAD/CAM – Concurrent Engineering

Introduction : (Maximum 5 sentences)
Cross-functional teams Include members from various disciplines involved in the process including manufacturing, hardware and software design, marketing and so forth.

Prerequisite knowledge for Complete understanding and learning of Topic:
General Engineering, Product design

Detailed content of the Lecture:

Manufacturing Planning and Control (MPC)

- The manufacturing planning and control (MPC) system is concerned with planning and
- Controlling all aspects of manufacturing, including
  - Managing materials,
  - Scheduling machines
  - People,
  - Coordinating suppliers and
  - Key customers.

- Because these activities change over time and respond differently to different markets and company strategies, provides a model for evaluating responses to changes in the competitive environment.
- We believe that the development of an effective manufacturing planning and control system is key to the success of any goods producing company.
- Moreover, truly effective MPC systems coordinate supply chains—joint efforts across company boundaries.
- Finally, MPC systems design is not a one-time effort;
- MPC systems need to continuously adapt and respond to
  - changes in the company environment,
  - strategy, customer requirements,
  - particular problems, and
  - new supply chain opportunities.

CAD / CAM Vs CIM

- Typical application of CAD/CAM
  Programming for NC , CNC and Industrial robots
  - ✓ Design of dies and moulds for casting
  - ✓ Dies for metal working operations
  - ✓ Design of tooling

- ✓ Quality control and inspection

- Computer integrated manufacturing includes all the engineering functions of CAD/CAM, but it also includes the firm's business functions that are related to Manufacturing
- CIM = CAD/ CAM functions + Business Functions
- The critical question is not what one has accomplished; it is
- "What should the firm, together with its supply chain partners, do next?"
  - ✓ The MPC system defined*:*
    1. What are the typical tasks performed by the MPC system and
    2. How do these tasks affect company operations?

  - ✓ An MPC system framework*:*
    1. What are the key MPC system components and
    2. How do they respond to a company's needs?

  - ✓ Matching the MPC system with the needs of the firm:
    1. How do supply-chain product, and
    2. Process issues affect MPC system design?

  - ✓ Evolution of the MPC system*:*
    1. What forces drive changes in the MPC system and
    2. How do companies respond to the forces?

Video Content / Details of website for further learning (if any):
https://study.com/academy/lesson/concurrent-models-in-software-engineering-types-applications.html

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 5-7

LECTURE HANDOUTS **L - 03**

MECH **Year/Sem : IV / VII**

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: CIM concepts – Computerised elements of CIM system –Types of production

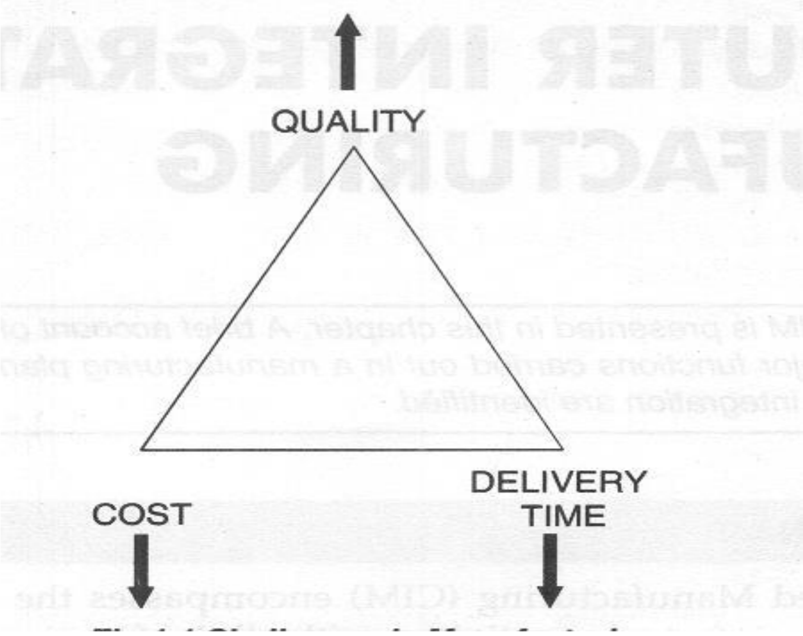
Introduction : (Maximum 5 sentences)
The term CIM denotes the widespread use of computer systems to design the product, to plan the production, control the operation, and perform the business related functions required in the manufacturing firm. True CIM includes integration of these functions in the system that operates throughout the enterprise.

Prerequisite knowledge for Complete understanding and learning of Topic:
CAD, CAM, Production, Business functions

Detailed content of the Lecture:

Computer Integrated Manufacturing (CIM)

- Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. The data required for various functions are passed from one application software to another in a seamless manner. For example, the product data is created during design. This data has to be transferred from the modeling software to manufacturing software without any loss of data. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory or a manufacturing facility
- This methodological approach is applied to all activities from the design of the product to customer support in an integrated way, using various methods, means and techniques in order to achieve production improvement, cost reduction, fulfillment of scheduled delivery dates, quality improvement and total flexibility in the manufacturing system. CIM requires all those associated with a company to involve totally in the process of product development and manufactureThe challenge before the manufacturing engineers is illustrated in Fig. 1



- Manufacturing industries strive to reduce the cost of the product continuously to remain competitive in the face of global competition. In addition, there is the need to improve the quality and performance levels on a continuing basis. Another important requirement is on time delivery. In the context of global outsourcing and long supply chains cutting across several international borders, the task of continuously reducing delivery times is really an arduous task. CIM has several software tools to address the above needs.
- Manufacturing engineers are required to achieve the following objectives to be competitive in a global context.
- Reduction in inventory
- Lower the cost of the product
- Reduce waste
- Improve quality
- Increase flexibility in manufacturing to achieve immediate and rapid response to:
- Product changes
- Production changes
- Process change
- Equipment change
- Change of personnel

- CIM technology is an enabling technology to meet the above challenges to the manufacturing.

Video Content / Details of website for further learning (if any):
https://www.slideshare.net/TSME108/components-of-cim

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 11-20

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LECTURE HANDOUTS

L - 04

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Manufacturing models and Metrics – Mathematical models of Production Performance
Introduction : (Maximum 5 sentences) In the physical sciences, a traditional mathematical model contains most of the following elements: Governing equations Supplementary sub-models Defining equations Constitutive equations Assumptions and constraints Initial and boundary conditions Classical constraints and kinematic equations
Prerequisite knowledge for Complete understanding and learning of Topic: Physical System, mathematical model, metrics

Detailed content of the Lecture:

- **PRODUCTION CONCEPTS AND MATHEMATICAL MODELS**
- A number of production concepts are quantitative, or require a quantitative approach to measure them.
- **Manufacturing lead time**
- Our description of production is that it consists of a series of individual steps: processing and assembly operations. Between the operations are material handling, storage, inspections, and other nonproductive activities. Let us therefore divide the activities in production into two main categories, operations and non-operation elements. An operation on a product (or work part) takes place when it is at the production machine. The non-operation elements are the handling, storage, inspections, and other sources of delay. Let us use to denote the lime per operation at a given machine or workstation, and to represent the non-operation time associated with the same machine. Further, let us suppose that there are separate machines or operations through which the product
- must be routed in order to be completely processed. If we assume a batch production situation, there are Q units of the product in the batch, A setup procedure is generally required to prepare each production machine for the particular product. The setup typically includes arranging the workplace and installing the tooling and fixturing required for the product. Let this setup time be denoted as T_m.
- Given these terms, we can define an important production concept, manufacturing lead time. The *manufacturing lead time* (MLT) is the total time required to process a given product (or work part) through the plant. We can express it as follows:

$$MLT = \sum_{i=1}^{n_m} \left(T_{sui} + QT_{oi} + T_{noi} \right)$$

- Where i indicates the operation sequence in the processing, i = 1 , 2 , . .n The MLT equation does not include the time the raw work part spends in storage before its turn in the production schedule begins.

- Let us assume that all operation times, setup times, and non-operation times are equal, respectively then MLT is given by

$$MLT = n_m \left(T_{su} + QT_o + T_{no} \right)$$

- For mass production, where a large number of units are made on a single machine, the MLT simply becomes the operation time for the machine after the setup has been completed and production begins.
- For flow-type mass production, the entire production line is set up in advance. Also, the non-operation time between processing steps consists simply of the time to transfer the product (or pan) from one machine or workstation to the next. If the workstations are integrated so that parts are being processed simultaneously at each station, the station with the longest operation time will determine the MLT value. Hence,

MLT= n_m (Transfer time +Longest T_o)

- In this case, n_m represents the number of separate workstations on the production line.
- The values of setup time, operation time, and non-operation time are different for the different production situations. Setting up a flow line for high production requires much more time than setting up a general-purpose machine in a job shop. However, the concept of how time is spent in the factory for the various situations is valid.

Production performance

- This report summarizes data on daily and weekly quantities of different parts produced by the FMS. The reports compare the actual quantities against the production schedule.
- Tooling reports provide information on various aspects of tool control, such as a listing of tools at each workstations and tool life status.
- The status report provides an instantaneous "snapshot" of the present condition of the FMS. Line supervision can request this report at any time to learn the current status of system operating parameters such as workstation utilization availability (reliability), cumulative piece counts, pallets and tooling.

Video Content / Details of website for further learning (if any):
https://www.montana.edu/dsobek/teaching/ime471/lectures/Lecture%206%20
20Manufacturing%20Models%20and%20Metrics.pdf

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 48-57

LECTURE HANDOUTS

L - 05

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Simple problems

Introduction : (Maximum 5 sentences)
A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. Mathematical models are used in the natural sciences (such as physics, biology, earth science, chemistry) and engineering disciplines (such as computer science, electrical engineering), as well as in non-physical systems such as the social sciences (such as economics, psychology, sociology, political science). Mathematical models are also used in music, linguistics and philosophy (for example, intensively in analytic philosophy).

Prerequisite knowledge for Complete understanding and learning of Topic:
Mathematical models, physical phenomenon,

Detailed content of the Lecture:
A flexible machining system consists of two machining workstations and a load/unload station. Station 1 is the load/unload station. Station 2 performs milling operations and consists of two servers (two identical CNC milling machines). Station 3 has one server that performs drilling (one CNC drill press). The stations are connected by a part handling system that has four work carriers. The mean transport time is 3.0 min. The FMS produces two parts, A and B. The part mix fractions and process routings for the two parts are presented in the table below. The operation frequency f_{ijk}= 1.0 for all operations. Determine: (a) maximum production rate of the FMS, (b) corresponding production rates of each product, (c) utilization of each station, and (d) number of busy servers at each station.

Part j	Part Mix P_j	Operation k	Description	Station i	Process Time t_{ijk} (min)
A	0.4	1	Load	1	4
		2	Mill	2	30
		3	Drill	3	10
		4	Unload	1	2
B	0.6	1	Load	1	4
		2	Mill	2	40
		3	Drill	3	15
		4	Unload	1	2

Solution: (a) To compute the FMS production rate, we first need to compute workloads at each station, so that the bottleneck station can be identified.

$WL_1 = (4+2)(0.4)(1.0) + (4+2)(0.6)(1.0) = 6.0\,\text{min}$.

$WL_2 = 30(0.4)(1.0) + 40(0.6)(1.0) = 36.0\,\text{min}$.

$WL_3 = 10(0.4)(1.0) + 15(0.6)(1.0) = 13.0\,\text{min}$.

The station routing for both parts is the same: $1 \rightarrow 2 \rightarrow 3 \rightarrow 1$. There are three moves, $n_1 = 3$.

$WL_4 = 3(3.0)(0.4)(1.0) + 15(0.6)(1.0) = 9.0\,\text{min}$.

The bottleneck station is identified by finding the largest WL_i/s_i ratio.

For station 1, $WL_1 / s_1 = 6.0/1 = 6.0\,\text{min}$.

For station 2, $WL_2 / s_2 = 36.0/2 = 18.0\,\text{min}$.

For station 3, $WL_3 / s_3 = 13.0/1 = 13.0\,\text{min}$.

For station 4, the part handling system, $WL_4 / s_4 = 9.0/4 = 2.25\,\text{min}$.

The maximum ratio occurs at station 2, so it is the bottleneck station that determines the maximum production rate of all parts made by the system.

$R_p{}^* = 2/36.0 = 0.0555\,pc/\text{min} = 3.333\,pc/hr$

(b) To determine production rate of each product, multiply $R_p{}^*$ by its respective part mix fraction.

$$R_{pA}{}^* = 3.33(0.4) = 1.333\,pc/hr$$

$$R_{pB}{}^* = 3.333(0.6) = 2.00\,pc/hr$$

(c) The utilization of each station can be computed using the equation:

$U_1 = (6.0/1)(0.05555) = 0.33$ (33.3%)

$U_2 = (36.0/2)(0.05555) = 1.0$ (100%)

$U_3 = (13.0/1)(0.05555) = 0.722$ (72.2%)

$U_4 = (9.0/4)(0.05555) = 0.125$ (12.5%)

(d) Mean number of busy servers at each station is determined using the equation:

$BS_1 = 6.0(0.05555) = 0.333$

$BS_2 = 36.0(0.05555) = 2.0$

$BS_3 = 13.0(0.05555) = 0.722$

$BS_4 = 9.0(0.05555) = 0.50$

We designed the preceding example so that most of the results could be verified without using the bottleneck model. For example, it is fairly obvious that station 2 is the limiting station, even with two servers. The processing times at the station are more than twice those at station 3. Given that station 2 is the bottleneck, let us try to verify the maximum production rate of the FMS, To do this, the reader should note that the processing times at station 2 are $t_{2A2} = 30$ min. and $t_{2B2} = 40$ min. Note also that the part mix fractions are $p_A = 0.4$ and $p_B = 0.6$. This means that for every unit of B produced there are 0.4/0.6 = 2/3 units part A. the corresponding time to process 1 unit of B and 2/3 unit of a at station 1 is

$\frac{2}{3}(30) + 1(40) = 20 + 40 = 60\,\text{min}$.

Sixty minutes is exactly the amount of processing time each machine has available in an hour. (this is no coincidence; we designed the problem so this would happen.) with two servers (two CNC mills), the FMS can produce parts at the following maximum rate:

$R_p{}^* = 2\left(\frac{2}{3} + 1\right) = 2(1.666) = 3.333\,pc/hr$

This is the same result obtained by the bottleneck model. Given that the bottleneck station is working at 100% utilization, it is easy to determine the utilizations of the other stations. At station 1, the time needed 10 load and unload the output of the two servers at station 2 is

$3.333(4+2) = 20.0\,\text{min}$.

As a fraction of 60 min. in an hour, this gives a utilization of u_j =0.333. At station 3, the processing time required to process the output of the two servers at station 2 is

$\frac{4}{3}(10) + 2(15) = 43.33\,\text{min}$.

As a fraction of the 60 min., we have U_3= 43.333/60 = 0.722. Using the same approach on the part handling system, we have

$\frac{4}{3}(9.0) + 2(9.0) = 30.0\,\text{min}$.

As a fraction of 60 min, this is 0.50. However, since there are four servers (four work carriers), this fraction is divided by 4 to obtain U_4= 0.125. These are the same utilization values as in our example using the bottleneck model.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=df5EK1P6Ph0

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :58-62

LECTURE HANDOUTS

L - 06

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Manufacturing Control

Introduction : (Maximum 5 sentences)
In a manufacturing control system, the processes to be carried out are carefully planned and executed according to the initial plan. A processing run of the chosen products is processed in a manufacturing facility as defined by the manufacturing model.

Prerequisite knowledge for Complete understanding and learning of Topic:
Manufacturing, Production, control

Detailed content of the Lecture:

Manufacturing Control

Manufacturing control is concerned with managing and controlling the physical operations in the factory.
Some of the manufacturing control are
1. Process monitoring and control 2. Quality 3. Shop floor control
4. Inventory Control 5. Just – in time production system

Manufacturing Planning and Control (MPC)

The manufacturing planning and control (MPC) system is concerned with planning and Controlling all aspects of manufacturing, including

- ✓ Managing materials,
- ✓ Scheduling machines
- ✓ People,
- ✓ Coordinating suppliers and
- ✓ Key customers.

Because these activities change over time and respond differently to different markets and company strategies, provides a model for evaluating responses to changes in the competitive environment.
We believe that the development of an effective manufacturing planning and control system is key to the success of any goods producing company.
Moreover, truly effective MPC systems coordinate supply chains—joint efforts across company boundaries.
Finally, MPC systems design is not a one-time effort;
MPC systems need to continuously adapt and respond to

- ✓ changes in the company environment,
- ✓ strategy, customer requirements,
- ✓ particular problems, and

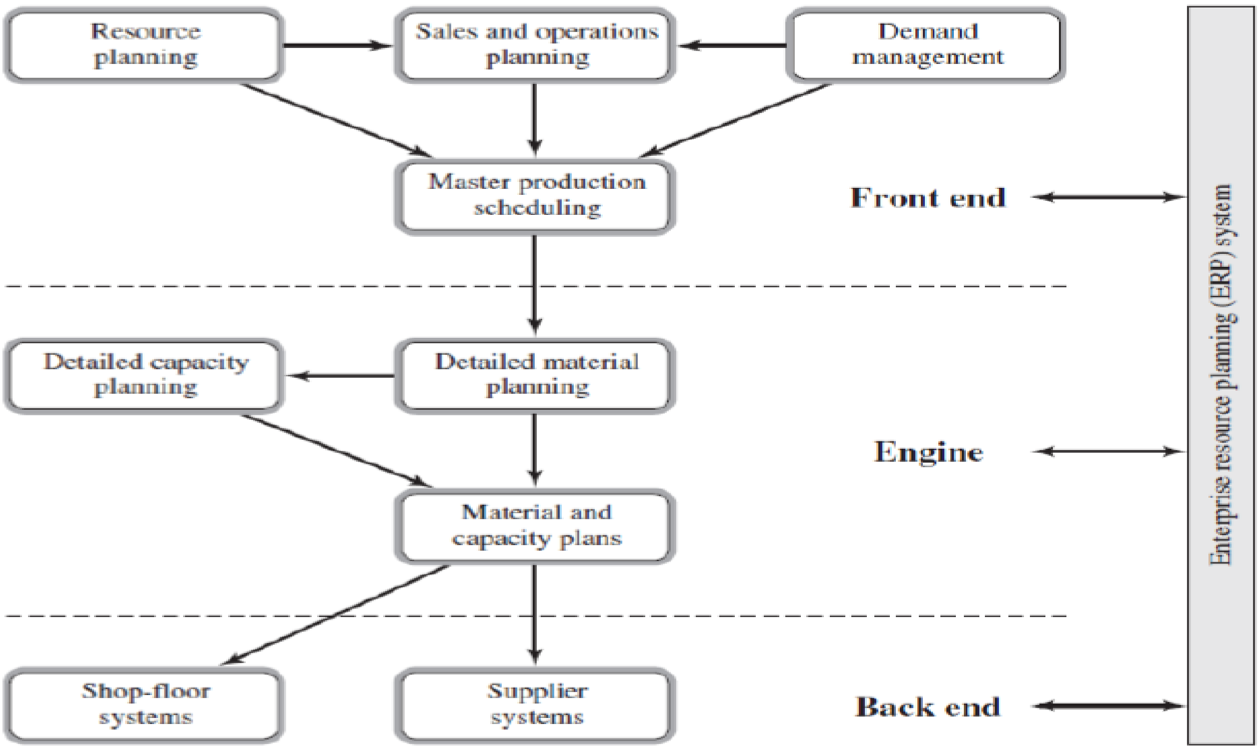
✓ new supply chain opportunities.

The critical question is not what one has accomplished; it is
"What should the firm, together with its supply chain partners, do next?"

• The MPC system defined:
– What are the typical tasks performed by the MPC system and
– How do these tasks affect company operations?

• An MPC system framework:
– What are the key MPC system components and
– How do they respond to a company's needs?

• Matching the MPC system with the needs of the firm:
– How do supply-chain product, and
– Process issues affect MPC system design?



Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=2SYeEt5vNec

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 23-39

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LECTURE HANDOUTS

L - 07

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Simple Problems

Introduction : (Maximum 5 sentences)
Enterprise control system integration between business systems, manufacturing execution systems and shop-floor process-control systems remains a key issue for facilitating the deployment of plant-wide information control systems for practical e-business-to-manufacturing industry-led issues. Achievement of the integration-in-manufacturing paradigm based on centralized/distributed hardware/software automation architectures is evolving using the intelligence-in-manufacturing paradigm addressed by IMS industry-led R&D initiatives. The remaining goal is to define and experiment with the next generation of manufacturing systems, which should be able to cope with the high degree of complexity required to implement agility, flexibility and reactivity in customized manufacturing. This introductory paper summarizes some key problems, trends and accomplishments in manufacturing plant control before emphasizing for practical purposes some rationales and forecasts in deploying automation over networks, holonic manufacturing execution systems and their related agent-based technology, and applying formal methods to ensure dependable control of these manufacturing systems.

Prerequisite knowledge for Complete understanding and learning of Topic:
Issues and challenges in manufacturing

Detailed content of the Lecture:
Networked Manufacturing Automation There is an increasing deployment of web technology to monitor the ubiquitous coherence between the physical flows of goods and the related information flows of services throughout product life cycles in production and logistics networks. These networking issues involve the twodimensional integration of automation (Galara and Hennebicq, 1999) for both vertical (synchronic) integration through the IEC/ISO 62264 standard for B2M applications and the IEC 61499 standard for SFC applications as well as horizontal (diachronic) integration through emanufacturing de facto standards for SCM and CRM applications. Among these interoperability issues between e-manufacturing applications, Neumann addresses in this special issue what is going on in communication in industrial automation to control the communication problems that arise from this increasing impact of the worldwide distribution of the Internet on the manufacturing automation domain

IMS Modeling and Experiments Intelligence in manufacturing is perceived in various ways ranging from intelligent control and information communication techniques through human intelligence in the operating/engineering loop (Lhote et al., 1999) to agents' self organization. The area of intelligent systems is challenging—to an extent occasionally verging on controversy—both the research community and the industrial sector to cope with the traditional and centralized automation approaches to meet the high degree of complexity and practical requirements for robustness, generality and reconfigurability in manufacturing control as well as in production management, planning and scheduling. Among many rationales, trends and experiments, a general consensus exists that holonic manufacturing systems (HMS) should be the unifying technology as well as the product– process engineering (PPE) approach for all product-driven control and management issues required by the customized manufacturing era

There is a growing demand for formalized methods in industrial automation engineering for dependability issues, to control the increasing complexity of software-intensive applications (Fig. 4) and their related ease-of-use techniques (Polzer, 2004). Another issue is to comply with fail-safety legacy certification (Moik, 2003), as safety for people and for industrial investments has become a key factor because of internationally accepted rules. Johnson addresses in this special issue the role of formal methods in improving automation software dependability. He points out the need for verification techniques to check the real software– hardware value-creation chain in industrial automation systems when addressing high levels of the organization (Table 2, levels 3 to 5), so that software dependability cannot affect the correctness of the control design and the reliability of the respective controllers in operation.

Many other issues should be debated to anticipate the next automation of manufacturing systems besides those presented in this special issue (Dolgui et al., 2006). One challenging approach could be to explore with more holism the appropriate balance between the increasing complexity of software-intensive systems (Fischer, 2006), ranging from embedded micro-systems to macro-systems of systems, and a more human-centered automation (Mayer and Stahre, 2006) for safety or ecoefficiency purposes. Another challenging approach could be to explore others modeling artifacts such as the promising System of Systems (Chen and Clothier, 2003) to cope with the high degree of complexity required to deploy plant-wide information control systems in enterprise.

Video Content / Details of website for further learning (if any):
https://hal.archives-ouvertes.fr/hal-00147431/document

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. : 40-43

LECTURE HANDOUTS

L - 08

MECH

Year/Sem : IV / VII

Course Name with Code : Computer Integrated Manufacturing / 16MED25

Course Faculty : Ms.S.Devadharshini

Unit : I- Introduction **Date of Lecture:**

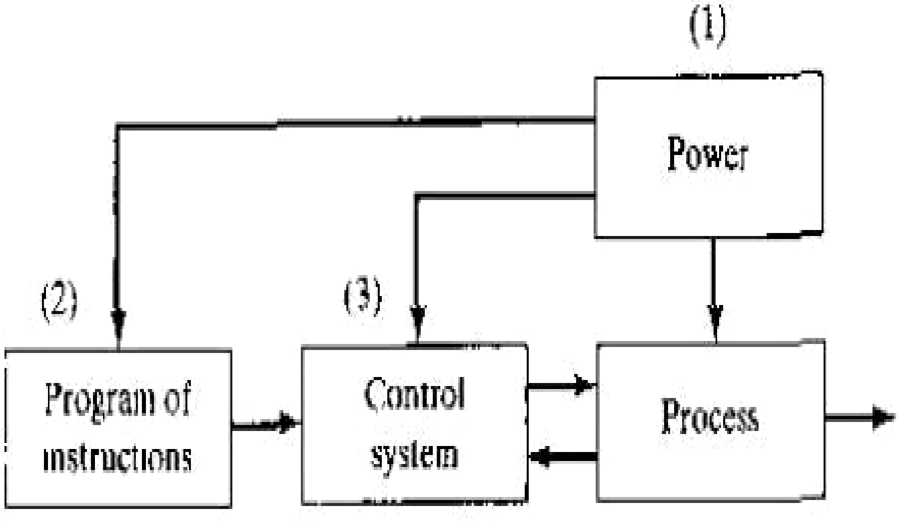
Topic of Lecture: Basic Elements of an Automated system

Introduction : (Maximum 5 sentences)
Automation consists of three basic elements: power; a programme of instructions; and a **control system** to actuate the instructions and sense feedback from the transformation **process**. Alternative power sources include: fossil fuels, solar energy, water and wind; however, their exclusive use is rare in automated systems.

Prerequisite knowledge for Complete understanding and learning of Topic:
Automation, Process, Transformation

Detailed content of the Lecture:

BASIC ELEMENTS AN AUTOMATED SYSTEM



Elements of an automated system: (1) power, (2) program of instructions, and (3) control systems.

An automated system consists of three basic elements:
Power to accomplish the process and operate the system. A program of instructions to direct the process, and
A control system to actuate the instructions.
The relationship amongst these elements is illustrated
in figure. All systems that qualify as being automated include these three basic elements in one form or another.
Power to Accomplish the Automated Process: An automated system is used to operate some process, and power is required to drive the processes as well as the controls. The principal source of power in automated systems is electricity. Electric power has many advantages in automated as well as non- automated processes
•Electrical power is widely available at moderate cost. It is an important part of our industrial infrastructure.
• Electrical power can be readily converted 10 alternative energy forms: mechanical, thermal, light, acoustic, hydraulic, and pneumatic.
• Electrical power at low levels can be used to accomplish functions such as signal transmission, information processing, and data storage and communication.
• Electrical energy can be stored in long-life batteries for use in locations where an external source of electrical power is not conveniently available.
Alternative power sources include fossil fuels, solar energy, water, and wind. However, their exclusive use is rare in automated systems. In many cases when alternative power sources used to drive the process itself, electrical power is used for the controls that automate the operation. For example, in casting or heat treatment, the furnace may be heated by fossil fuels. But the control system to regulate temperature and time cycle is electrical. In other cases, the energy from these alternative sources is converted to electric power to operate both the process and its automation.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=cSArdiJ70dM

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :69-84

LECTURE HANDOUTS

L - 09

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

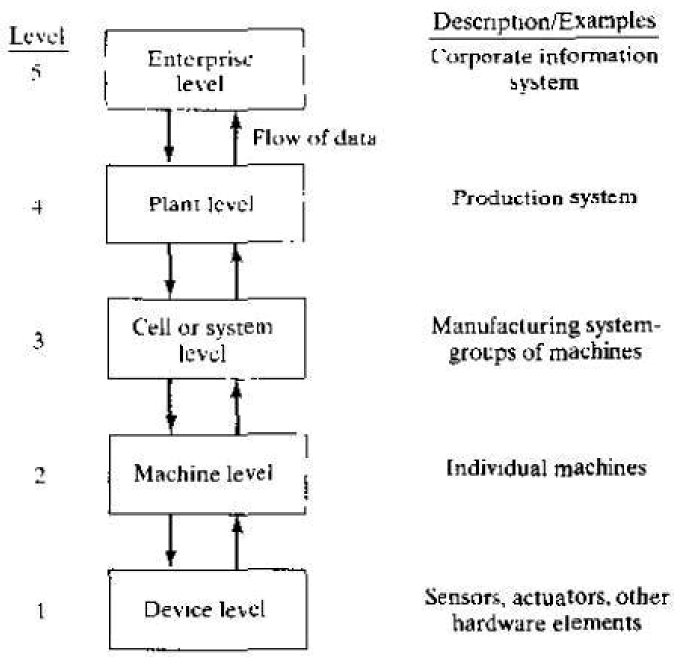
Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Levels of Automation

Introduction : (Maximum 5 sentences)
Automation is the creation and application of technologies to produce and deliver goods and services with minimal human intervention. The implementation of **automation** technologies, techniques and processes improve the efficiency, reliability, and/or speed of many tasks that were previously performed by humans.

Prerequisite knowledge for Complete understanding and learning of Topic:
Automation, process, manufacturing

Detailed content of the Lecture:
LEVELS OF AUTOMATION:
The concept of automated systems can be applied to various levels of factory operations.
One normally associates automation with the individual production machines. However, the production machine itself is made up of subsystems that may themselves be automated.



Five levels of automation and control in manufacturing.

Device level:

This is the lowest level in our automation hierarchy. It includes the actuators, sensors, and other hardware components that comprise the machine level. The devices are combined into the individual control loops of the machine.

Machine level:

Hardware at the device level is assembled into individual machines. Examples include CNC machine tools and similar production equipment, industrial robots, powered conveyors, and automated guided vehicles. Control functions at this level include performing the sequence of steps in the program of instructions in the correct order and making sure that each step is properly executed.

Cell or system level: This is the manufacturing cell or system level, which operate under instructions from the plant level. A manufacturing cell or system is a group of machines or workstations connected and supported by a material handling system, computer. and other equipment appropriate to the manufacturing process. Production lines are included in this level. Functions include part dispatching and machine loading. Coordination among machines, material handling system, and collecting and evaluating inspection data.

Plant level : This is the factory or production systems level. It receives instructions from the corporate information system and translates them into operational plans for production. Likely functions include: order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control, and quality control.

Enterprise level: This is the highest level consisting of the corporate information system. It is concerned with all of the functions necessary to manage the company. Marketing and sales, accounting, design, research, aggregate planning, and master production scheduling.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=S36q6gs1yek

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :84-86

LECTURE HANDOUTS

L - 10

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **I- Introduction** **Date of Lecture:**

Topic of Lecture: Lean Production and Just-In-Time Production

Introduction : (Maximum 5 sentences)
Just-in-time manufacturing is focused on efficiency, while lean manufacturing is focused on using efficiency to add value for the customer. Just-in-time manufacturing can be practiced on its own or as one step in the lean manufacturing process." There are other ways JIT and Lean differ.

Prerequisite knowledge for Complete understanding and learning of Topic:
Lean concepts, Just in time, procurement

Detailed content of the Lecture:
LEAN PRODUCTION.
Lean production can he defined as an adaptation of mass production in which workers and work cells are made more flexible and efficient by adopting methods that reduce waste in all forms. According to another author of The Machine that Changed the World, lean production is based on four principles
1. Minimize waste
2. Perfect first-time quality
3. Flexible production lines
4. Continuous improvement

Minimize Waste: All four principles of lean production are derived from the first principle: minimize waste.
(1)Production of defective parts,
(2) Production of more than till number of items needed,
(3) Unnecessary inventories,
(4) Unnecessary processing steps,
(5) Unnecessary movement of people,
(6) Unnecessary transport of materials, and
(7) Workers waiting.

Perfect First-Time Quality: In the area of quality, the comparison between mass production and lean production provides a sharp contrast. In mass production, quality control is defined in terms of an acceptable quality level. This means that a certain level of fraction defects is sufficient, even satisfactory. In lean production, by contrast, perfect quality is required. The just-in-time delivery discipline used in lean production necessitates a zero defects level in parts quality, because if the part delivered to the downstream workstation is defective, production stops. There is minimum inventory in a lean system to act as a buffer. In mass production, inventory buffers are used just in case these quality problems occur. The defective work units are simply taken off the line and replaced with acceptable units; However, the problem is that such a policy tends to perpetuate the cause of the poor quality. Therefore, defective parts continue to be produced. In lean production a single defect draws attention to the quality problem, forcing corrective action and a permanent solution. Workers inspect their own production, minimizing the delivery of defects to the downstream production station.

Flexible Production Systems: In mass production, the goal is to maximize efficiency. This is achieved using long production runs of identical parts. Long production runs tolerate long setup changeovers, In lean production procedures are designed to speed the changeover. Reduced setup times allow for smaller batch sizes. Thus providing the production system with greater flexibility. Flexible production systems were needed in Toyota's comeback period because of the much smaller car market in Japan and the need to be as efficient as possible.

Continuous Improvement: In mass production, there is a tendency to set up the operation, and if it is working, leave it alone. Mass production lives by the motto ―if it ain't broke, don't fix it." By contrast lean production supports the policy of continuous improvement. Continuous improvement means constantly searching for and implementing ways to reduce cost, improve quality, and increase productivity.

The scope of continuous improvement goes beyond factory operations and involves design improvements as well. Continuous improvement is carried out one project at a time. The projects may be concerned with any of the following problem areas: cost reduction. Quality improvement, productivity improvement, setup time reduction, cycle time reduction, manufacturing lead

time and work-in-process inventory reduction, and improvement of product design to increase performance and customer appeal.

JUST-IN-TIME MANUFACTURING (JIT)

Just-in-time (JIT) manufacturing, also known as just-in-time production or the Toyota Production System (TPS), is a methodology aimed primarily at reducing flow times within production system as well as response times from suppliers and to customers. Its origin and development was in Japan, largely in the 1960s and 1970s and particularly at Toyota.

Just in Time (JIT), as the name suggests, is a management philosophy that calls for the production of what the customer wants, when they want it, in the quantities requested, where they want it, without it being delayed in inventory.

So instead of building large stocks of what you think the customer might want you only make exactly what the customer actually asks for when they ask for it. This allows you to concentrate your resources on only fulfilling what you are going to be paid for rather than building for stock.

Within a Just in Time manufacturing system, each process will only produce what the next process in sequence is calling for.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=AH5Bn8iguNM

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :44-46, 325

LECTURE HANDOUTS

L - 11

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Process planning – Computer Aided Process Planning (CAPP)

Introduction : (Maximum 5 sentences)

Process planning is a preparatory step before manufacturing, which determines the sequence of operations or **processes** needed to produce a part or an assembly. This step is more important in job shops, where one-of-a-kind products are made or the same product is made infrequently.

Prerequisite knowledge for Complete understanding and learning of Topic:

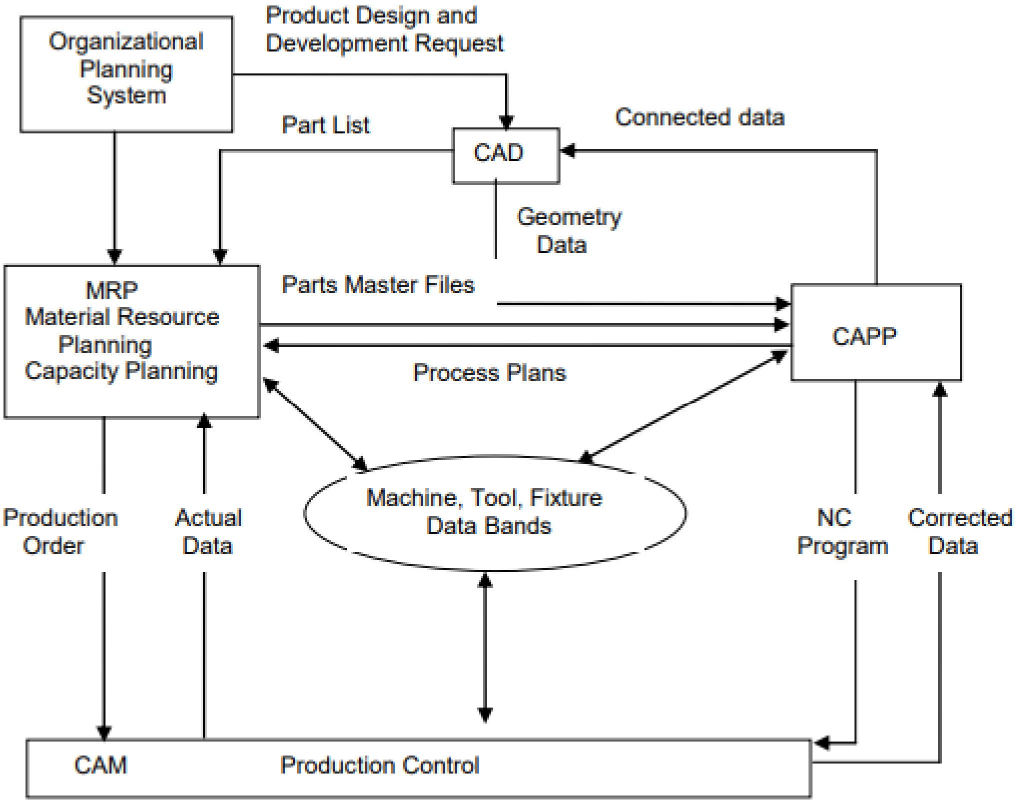
Process, production, route sheet

Detailed content of the Lecture:

PROCESS PLANNING

Products and their components are designed to perform certain specific functions. Every product has some design specifications which ensure its functionality aspects. The task of manufacturing is to produce components such that they meet design specifications. Process planning acts as a bridge between design and manufacturing by translating design specifications into manufacturing process details. It refers to a set of instructions that are used to make a component or a part so that the design specifications are met, therefore it is major determinant of manufacturing cost and profitability of products. Process planning answers the questions regarding required information and activities involved in transforming raw materials into a finished product. The process starts with the selection of raw material and ends with the completion of part.

Computer-aided process planning (CAPP) It helps determine the processing steps required to make a part after CAP has been used to define what is to be made. CAPP programs develop a process plan or route sheet by following either a variant or a generative approach. The variant approach uses a file of standard process plans to retrieve the best plan in the file after reviewing the design. The plan can then be revised manually if it is not totally appropriate. The generative approach to CAPP starts with the product design specifications and can generate a detailed process plan complete with machine settings. CAPP systems use design algorithms, a file of machine characteristics, and decision logic to build the plans. Expert systems are based on decision rules and have been used in some generative CAPP systems. CAPP has recently emerged as the most critical link to integrated CAD/CAM system into inter-organizational flow. Main focus is to optimize the system performance in a global context. The essentiality of computer can easily be understood by taking an example, e.g. if we change the design, we must be able to fall back on a module of CAPP to generate cost estimates for these design changes. Similarly for the case of the breakdown of machines on shop floor. In this case, alternative process plan must be in hand so that the most economical solution for the situation can be adopted. Fig 2 is one such representation, where setting of multitude of interaction among various functions of an organization and dynamic changes that takes place in these sub functional areas have been shown. Hence, the use of computer in process planning is essential



CAPP is the application of computer to assist the human process planer in the process planning function. In its lowest form it will reduce the time and effort required to prepare process plans and provide more consistent process plan. In its most advanced state, it will provide the automated interface between CAD and CAM and in the process achieve the complete integration with in CAD/CAM.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=y24meNZbUoU

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :719-725

LECTURE HANDOUTS

L - 12

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Logical steps in Computer Aided Process Planning

Introduction : (Maximum 5 sentences)
Computer-aided process planning (**CAPP**) is the use of computer technology to aid in the process planning of a part or product, in manufacturing. **CAPP** is the link between CAD and CAM in that it provides for the planning of the process to be used in producing a designed part.

Prerequisite knowledge for Complete understanding and learning of Topic:
Process plan, route sheet, production

Detailed content of the Lecture:

Logical steps in Computer Aided Process Planning

The uses of computers in process plan have following advantages over manual experience-based process planning :

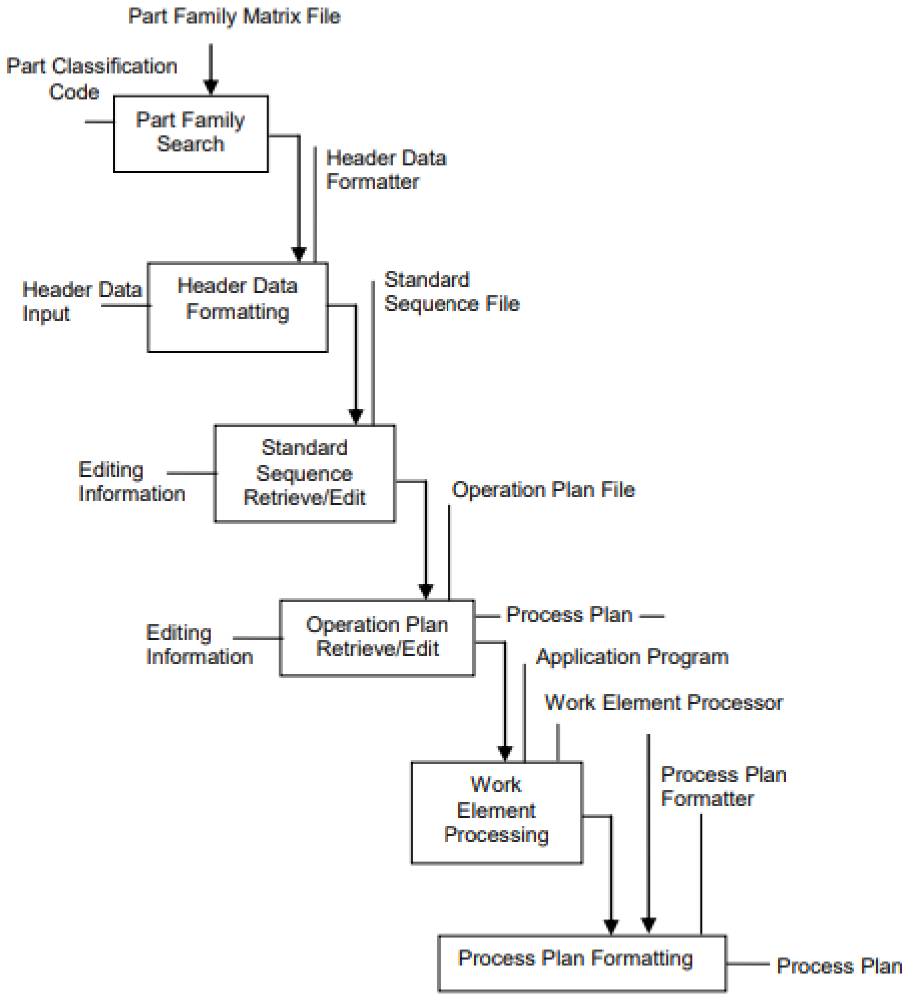
(i) It can systematically produce accurate and consistent process plans.
(ii) It leads to the reduction of cost and lead times of process plan.
(iii) Skill requirement of process planer are reduced to develop feasible process plan.
(iv) Interfacing of software for cost, manufacturing lead time estimation, and work standards can easily be done.
(v) Leads to the increased productivity of process planar.

With the emergence of CIM as predominate thrust area in discrete part industries process planning has received significant attention, because it is the link between CAD and CAM. Hence, computer aided process planning (CAPP) has become a necessary and vital objective of CIM system.

Now-a-days, rapid progress is being made in the automation of actual production process and also the product design element. However, the interface between design and production presents the greatest difficulty in accomplishing integration. CAPP has the potential to achieve this integration. In general, a complete CAPP system has following steps :

(i) Design input
(ii) Material selection
(iii) Process selection
(iv) Process sequencing
(v) Machine and tool selection
(vi) Intermediate surface determination
(vii) Fixture selection

(viii) Machining parameter selection
(ix) Cost/time estimation
(x) Plan preparation
(xi) Mc tape image generation.



Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=viUNH5iGIBA

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :726-728

LECTURE HANDOUTS

L - 13

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Aggregate Production Planning and the Master Production Schedule

Introduction : (Maximum 5 sentences)
The **aggregate plan** provides an overall guideline for **master production scheduling** which specifies the timing and volume of the **production** of individual products. The **master** scheduler takes the **aggregate** decisions as targets and tries to achieve them as much as possible.

Prerequisite knowledge for Complete understanding and learning of Topic:
Scheduling, plan,

Detailed content of the Lecture:

AGGREGATE PLANNING AND MASTER SCHEDULING

Aggregate planning is the process of planning the quantity and timing of output over the intermediate range (often 3 to 18 months) by adjusting the production rate, employment, inventory, and other controllable variables. Aggregate planning links long-range and short-range planning activities. It is "aggregate" in the sense that the planning activities at this early stage are concerned with homogeneous categories (families) such as gross volumes of products or number of customers served.

Master scheduling follows aggregate planning and expresses the overall plan in terms of the amounts of specific end items to produce and dates to produce them. It uses information from both forecasts and orders on hand, and it is the major control (driver) of all production activities.

VARIABLES USED IN AGGREGATE PLANNING

Aggregate planning is a complex problem largely because of the need to coordinate interacting variables in order for the firm to respond to the (uncertain) demand in an effective way. Table below identifies some of the key variables available to planners and the costs associated with them.

	Decision variable		Associated cost
1.	Varying size of work force	1.	Hiring, training, and layoff costs
2.	Using overtime or accepting idle time	2.	Wage premiums and non-productive timecosts
3.	Varying inventory levels	3.	Carrying and storage costs
4.	Accepting back orders	4.	Stockout costs of lost orders
5.	Subcontracting work to others	5.	Higher labour and material costs
6.	Changing the use of existing capacity	6.	Delayed response and higher fixed costs

To best understand the effect of changes in these variables, it is useful to first focus upon the impact of a change in only one variable at a time, with other variables held constant.

AGGREGATE PLANNING STRATEGIES

Several different strategies have been employed to assist in aggregate planning. Three "pure"strategies are recognized. The pure strategies stem from early models that depicted production results when only one of the decision variables was permitted to vary all others being held constant. Three focused strategies are:

1. **Vary production to match demand by changes in employment (Chase demand strategy):** This strategy permits hiring and layoff of workers, use of overtime, and subcontracting as required in each period. However, inventory build-up is not used.

2**. Produce at a constant rate and use inventories. (Level production strategy):** This strategy retains a stable work force producing at a constant output rate. Inventory can be accumulated to satisfy peak demands. In addition, subcontracting is allowed and back orders can be accepted.Promotional programs may also be used to shift demand.

3. **Produce with stable workforce but vary the utilization rate (Stable work-force strategy)**: This strategy retains a stable work force but permits overtime, part-time, and idle time. Some versions of this strategy permit back orders, subcontracting, and use of inventories. Although this strategy uses overtime, it avoids the detrimental effects of layoff.

MIXED STRATEGIES The number of mixed strategy alternative production plans is almost limitless. However, the realities of the situation will most likely limit the number of practical solutions. These can be evaluated on a trial and error basis to find which plan best satisfies the requirements, taking cost, employment policies, etc., into account.

Master Production Schedule

Products included in the MPS divide into 3 categories:

(1) firm customer orders, (2) forecasted demand, & (3) spare parts.

Proportions in each category vary for different companies, & in some cases one or more categories are omitted. Companies producing assembled products will generally have to handle all three types. In the case of customer orders for specific products, the company is usually obligated to deliver the item by a particular date that has been promised by the sales department. In the second category, production output quantities are based on statistical forecasting techniques applied to previous demand patterns, estimates by the sales staff, & other sources.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Ic_El2DkpjA

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :737-741

MUTHAYAMMAL ENGINEERING COLLEGE
(An Autonomous Institution)
(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L - 14

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Material Requirement planning

Introduction : (Maximum 5 sentences)

Material requirements planning (**MRP**) is a system for calculating the **materials** and components needed to manufacture a product. It consists of three primary steps: taking inventory of the **materials** and components on hand, identifying which additional ones are needed and then scheduling their production or purchase.

Prerequisite knowledge for Complete understanding and learning of Topic:

Procurement, scheduling

Detailed content of the Lecture:

MATERIAL REQUIREMENT PLANNING

Material requirement planning is not only a technique for planning "material" requirements. It is also a logic that relates all the activities in a company to customer demands. People can manage all the resources in a company by using MRP logic together with data processing in other areas. This entire system is called a Manufacturing Resources Planning System, or MRP II. With the introduction of technological enhancements such as open systems platforms and client/server architecture, MRP II systems are now evolving into Enterprise Resource Planning Systems (ERP). An ERP system plans not only the allocation of manufacturing resources but also other resources, and has applications in service as well as manufacturing industries. In this book, we concentrate our discussion on manufacturing.

Nature of Demands

All systems are implemented to satisfy customers' demand. There are different sources of demand for a product and its component items. Some item requirements are determined by the needs of other items while others are specified by customers. The former requirements also come from customers, but indirectly. Item requirements can be classified as dependent and independent demands.

- Independent demand
  Demand for an item that is unrelated to the demand for other items. Demand for finished goods, parts required for destructive testing, and service part requirements are examples of independent demand.
- Dependent demand
  Demand that is directly related to or derived from the bill of material structure for other items or end products. Such demands are calculated and need not be forecasted. A given inventory item may have both dependent and independent demand at any given time. For example, a part may simultaneously be used as a component of an assembly and also sold as a service part. Production to meet dependent demand should be scheduled so as to explicitly recognize its linkage to production intended to meet independent demand.

MRP Input Data

MRP is to translate the requirement of end products stated in MPS into the requirement of components and materials. MPS is the most direct input to MRP. Other input data include inventory status, bill of material (BOM), fundamental data in item master file, and shop calendar.

- MPS

  MPS is the schedule for end items. It states the quantity and timing of production of specific end items. Master production scheduling is a procedure to determine the production schedules and the available-to-promise (ATP) of the end products. Based on MPS, MRP calculates the replenishment plans from the items in the level below the end products down to the raw materials
- BOM

  BOM describes the structure of the products. It states, from level to level, the components needed to make the parent items. By using BOM, the requirements of end products are expanded to include the requirements of the components, and hence the requirements of all the lower level materials.
- Inventory Status

  In expanding the lower level requirements, what we obtain are gross requirements. Gross requirement is not the real requirement. Net requirement is calculated by subtracting the inventory from the gross requirement. Since MRP is time-phased, both on-hand and on-order inventories are considered. On-hand inventory is the present inventory; on-order inventory is the future inventory, and has to be represented by both quantity and receiving date.
- Fundamental data in item master file

  The attributes of all items including raw materials, works-in-process, semi-finished goods, or finished goods, are expressed in the item master file. Part number, lead-time, safety stock, lot-sizing rule, low level code, etc. are required by the MRP processor. Low level code is used to determine the sequence of MRP calculation. Safety stock and lot-sizing rule are used to decide the quantity of the material replenishments. Lead-time is used to decide the time to replenish the required materials.
- Shop Calendar

  MRP systems are time-phased. Time bucket is an interval used to break time into discrete chunks. The length of a time bucket is defined according to the characteristics of a business. Commonly used time bucket includes week and day, i.e., numbered-week calendar (00-99) and numbered-day calendar (M-day calendar, 000-999). Planning horizon is the amount of time the master schedule and MRP extend into the future. The planning horizon should cover at least the cumulative lead-time to produce a product.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=1kU8HG5Y9Kc

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :741-747

LECTURE HANDOUTS

L - 15

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Capacity Planning- Control Systems

Introduction : (Maximum 5 sentences)
Capacity planning is the process of determining the production **capacity** needed by an organization to meet changing demands for its products. In the context of **capacity planning**, design **capacity** is the maximum amount of work that an organization is capable of completing in a given period.

Prerequisite knowledge for Complete understanding and learning of Topic:
Capacity of an industry, process plan, MRP

Detailed content of the Lecture:

Capacity planning

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, design capacity is the maximum amount of work that an organization is capable of completing in a given period. Effective capacity is the maximum amount of work that an organization is capable of completing in a given period due to constraints such as quality problems, delays, material handling, etc.

The phrase is also used in business computing and information technology as a synonym for capacity management. IT capacity planning involves estimating the storage, computer hardware, software and connection infrastructure resources required over some future period of time. A common concern of enterprises is whether the required resources are in place to handle an increase in users or number of interactions.Capacity management is concerned about adding central processing units (CPUs), memory and storage to a physical or virtual server. This has been the traditional and vertical way of scaling up web applications, however IT capacity planning has been developed with the goal of forecasting the requirements for this vertical scaling approach.A discrepancy between the capacity of an organization and the demands of its
customers results in inefficiency, either in under-utilized resources or unfulfilled customers. The goal of capacity planning is to minimize this discrepancy. Demand for an organization's capacity varies based on changes in production output, such as increasing or decreasing the production quantity of an existing product, or producing new products. Better utilization of existing capacity can be accomplished through improvements in overall equipment effectiveness (OEE). Capacity can be increased through introducing new techniques, equipment and materials, increasing the number of workers or machines, increasing the number of shifts, or acquiring additional production facilities.

Capacity is calculated as (number of machines or workers) × (number of shifts) × (utilization) × (efficiency)

Strategies

The broad classes of capacity planning are lead strategy, lag strategy, match strategy, and adjustment strategy.

- **Lead strategy** is adding capacity in anticipation of an increase in demand. Lead strategy is an aggressive strategywith the goal of luring customers away from the company's competitors by improving the service level and reducing lead time. It is also a strategy aimed at reducing stockout costs. A large capacity does not necessarily imply high inventory levels, but it can imply higher cycle stock costs. Excess capacity can also be rented to other companies.

- Advantage of lead strategy: First, it ensures that the organization has adequate capacity to meet all demand, even during periods of high growth. This is especially important when the availability of a product or service is crucial, as in the case of emergency care or hot new product. For many new products, being late to market can mean the difference between success and failure. Another advantage of a lead capacity strategy is that it can be used to preempt competitors who might be planning to expand their own capacity. Being the first in an area to open a large grocery or home improvement store gives a retailer a define edge. Finally many businesses find that overbuilding in anticipation of increased usage is cheaper and less disruptive than constantly making small increases in capacity. Of course, a lead capacity strategy can be very risky, particularly if demand is unpredictable or technology is evolving rapidly.
- **Lag strategy** refers to adding capacity only after the organization is running at full capacity or beyond due to increase in demand (North Carolina State University, 2006). This is a more conservative strategy and opposite of a lead capacity strategy. It decreases the risk of waste, but it may result in the loss of possible customers either by stockout or low service levels. Three clear advantages of this strategy are a reduced risk of overbuilding, greater productivity due to higher utilization levels, and the ability to put off large investments as long as possible. Organization that follow this strategy often provide mature, cost-sensitive products or services.
- **Match strategy** is adding capacity in small amounts in response to changing demand in the market. This is a more moderate strategy.
- **Adjustment strategy** is adding or reducing capacity in small or large amounts due to consumer's demand, or, due to major changes to product or system architecture.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=m0eSxQfJ360

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :747-749

LECTURE HANDOUTS | **L - 16**

MECH | **Year/Sem : IV / VII**

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning** **Date of Lecture:**

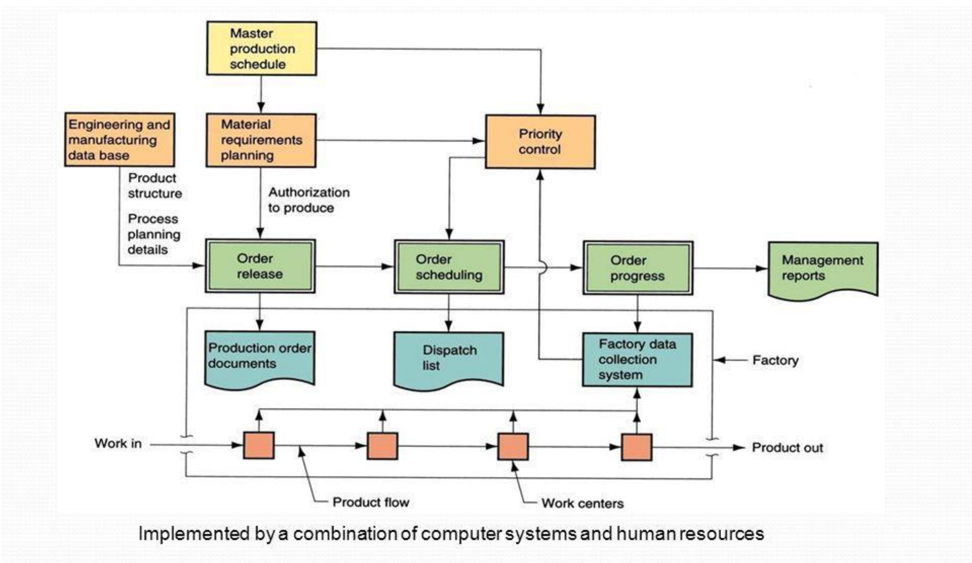
Topic of Lecture: Shop Floor Control-Inventory Control

Introduction : (Maximum 5 sentences)
A system of computers and/or controllers tools used to schedule, dispatch and track the progress of work orders through **manufacturing** based on defined routings.

Prerequisite knowledge for Complete understanding and learning of Topic:
Shop floor activities, capacity planning, Inventory

Detailed content of the Lecture:
SHOP FLOOR CONTROL

Shop floor control is concerned with the release of production orders to the factory, monitoring and controlling the progress of the orders through the various work centers, and acquiring current information on the status of the orders. A typical shop floor control system consists of three phases: (1) order release, (2) order scheduling, and (3) order progress. The three phases and their connections to other functions in the production management system are pictured in Figure 26.9. In today's implementation of shop floor control, these phases are executed hy a com hi nation of computer and human resources, with a growing proportion accomplished by computer automated methods.



Order Release

He order release phase of shop floor control provides the documentation needed to process a production order through the factory. The collection of document is sometimes called the shop packet. It consists of: (1) the route sheet, which documents the process plan for the item to be produced: (2) material requisitions [0 draw the necessary raw materials from inventory: (3)job cards or other means to report direct labor time devoted to the order and to indicate progress of the order through the factory; (4) move tickets to authorize the material handling personnel to transport parts between work centers in the factory if this kind of authorization is required; and (5) parts list, if required for assembly jobs.

Order Scheduling

The order scheduling module follows directly from the order release module and assigns the production orders to the various work centers in the plant. In effect, order scheduling executes the dispatching function in PTC. The order scheduling module prepares a *dispatch list,* which indicates which production orders should be accomplished at the various work centers. It also provides information about relative priorities of the different jobs, for example, by showing due dates for each job. In current shop floor control practice, the dispatch list guides the shop foreman in making Work assignments and allocating resources to different jobs so that the master schedule can best be achieved. The order scheduling module in shop floor control is intended to solve two problems in production control: (1) machine loading and (2) job sequencing. some of the dispatching rules used to establish priorities for production orders in the plant include:'

- First-come-first serve. Jobs are processed in the order in which they arrive at the machine. One might argue that this rule is the most fair.
- Earliest due date. Orders with earlier due dales are given higher priorities.
- Shortest processing time. Orders with shorter processing times are given higher priorities.
- Least slack time. Slack lime is defined as the difference between the time remaining until due date and the process time remaining. Orders with the least slack in their schedule are given higher priorities.
- Critical ratio. The critical ratio is defined as the ratio of the time remaining until due date divided by the process time remaining. Orders with the lowest critical ratio are given higher priorities.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=ULhGiQCADGg

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :749-756

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LECTURE HANDOUTS

L - 17

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Brief on Manufacturing Resource Planning-II

Introduction : (Maximum 5 sentences)

Manufacturing resource planning (**MRP II**) is defined as a method for the effective **planning** of all **resources** of a **manufacturing** company. Ideally, it addresses operational **planning** in units, financial **planning**, and has a simulation capability to answer "what-if" questions and extension of closed-loop **MRP**.

Prerequisite knowledge for Complete understanding and learning of Topic:

Resources of an industry, operational plan

Detailed content of the Lecture:

MANUFACTURING RESOURCE PLANNING (MRP II)

Manufacturing resource planning can be defined as a computer-based system for planning, scheduling, and controlling the materials, resources, and supporting activities needed to meet the MP& MRP II is a closed-loop system that integrates and coordinates all of the major functions of the business to produce the right products at the right times.

The term "closed-loop system" means that MRP II incorporates feedback of data on various aspects of operating performance so that corrective action can be taken in a timely manner; that is,MRP II includes a shop floor control system.

Application modules typically provided in a high-end MRP II system include the following:

• Management planning. Functions included in this module are business strategy, aggregate production planning, master production scheduling, rough-cut capacity planning. and budget planning

• Customer service. Typical components in this module are sales forecasting, order entry, sales analysis, and finished goods inventory.

• Operations planning. This is the MRP module. enhanced with capacity requirements planning. The output consists of purchase order and work order releases.

• Operations execution. This includes purchasing, production scheduling and control, WIP inventory control, shop floor control and labour hour tracking.

• Financial functions. These include cost accounting, accounts receivable, account, payable, general ledger. and payroll..

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=iyOKUdJgKJ4

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :762

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LECTURE HANDOUTS

L - 18

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning**

Date of Lecture:

Topic of Lecture: Enterprise Resource Planning (ERP) - Simple Problems.

Introduction : (Maximum 5 sentences)

Enterprise resource planning (**ERP**) is defined as the ability to deliver an integrated suite of business applications. **ERP** tools share a common process and data model, covering broad and deep operational end-to-end processes, such as those found in finance, HR, distribution, manufacturing, service and the supply chain.

Prerequisite knowledge for Complete understanding and learning of Topic:

MRP, MRP-II, Process plan, capacity planning, MPS

Detailed content of the Lecture:

Enterprise resource planning(ERP)

It is the integrated management of core business processes, often in real-time and mediated by software and technology.

ERP is usually referred to as a category of business-management software — typically a suite of integrated applications—that an organization can use to collect, store, manage, and interpret data from these many business activities.

ERP provides an integrated and continuously updated view of core business processes using common databases maintained by a database management system. ERP systems track business resources—cash, raw materials, production capacity—and the status of business commitments: orders, purchase orders, and payroll. The applications that make up the system share data across various departments (manufacturing, purchasing, sales, accounting, etc.) that provide the data. ERP facilitates information flow between all business functions and manages connections to outside stakeholders.

Enterprise system software is a multibillion-dollar industry that produces components supporting a variety of business functions. IT investments have become the largest category of capital expenditure in United States-based businesses over the past decade. Though early ERP systems focused on large enterprises, smaller enterprises increasingly use ERP systems.

The ERP system integrates varied organizational systems and facilitates error-free transactions and production, thereby enhancing the organization's efficiency. However, developing an ERP system differs from traditional system development. ERP systems run on a variety of computer hardware and network configurations, typically using a database as an information repository.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=PVRgIXLWDHs

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :763

LECTURE HANDOUTS

L - 19

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning** **Date of Lecture:**

Topic of Lecture: Simple Problems.

Introduction : (Maximum 5 sentences)
ERP stands for **enterprise resource planning**, but what does **ERP** mean? The simplest way to define **ERP** is to think about all the core processes needed to run a company: finance, HR, manufacturing, supply chain, services, procurement, and others.

Prerequisite knowledge for Complete understanding and learning of Topic:
finance, HR, manufacturing, supply chain, services, procurement

Detailed content of the Lecture:

An ERP implementation is one of the most intense changes a company can undergo. It can cost from a couple of hunderd thousands to even millions. The change that the new system causes is going to be experienced by each employee of the company. And because of the scale of the project it can form, when not approached correctly, a minefield of mistakes, delays and hiccups.

Here is a Top 10 of ERP implementation issues and their solutions.

Issue #1:

Not making a (clear) definition or planning of your requirements.

Solution:

Your business processes and needs are unique for your business, so they should be the starting point for the decision-making proces of an (new) ERP system. These processes and needs should be written down and fully understood before a well-considered choice is made in the wide offer of ERP systems. With this examination a more productive conversation can be started with the software vendor. Now you know what you want and the vendor has a better view of how to help you. The vendor can help you make a selection in the many options and choices that best fit your company.

Issue #2:

Unrealistic expectations and wishes.

An ERP system is not an 'Easy Button' that solves all your companies' problems easily and painlessly. A lot of companies forget to see the bigger picture.

Solution:

An ERP system is showing that it was worth the investment in the long run and realise the implementation is not without effort and pain.

You can set the bar high for getting the optimal results, but not for instant satisfaction of your needs!

Issue #3:

Not taking advantage of all features of the software.

Solution:

Current ERP systems are more helpful then ever. The list of features keeps growing and expanding. A big mistake companies make is not fully taking advantage of the software's full potential. You and your ERP implementation team need to know the new system thoroughly and need to ask the vendor as much questions as possible. Your team needs to know how to use the ERP system for your business. The best way to get the highest ROI out of your ERP system is to use every feature for all of your business processes.

Less then half of companies understand the features if their software fully (source: Yearly ERP-report computerworld.nl). That is shocking knowing the investment of such a system can run up to millions.

Make a main list of all features, how much they are used and periodically update this list to see which one is being used most and is most efficient. This knowledge catalog can be used to train new employees, to write testscripts and to help with the audit, compliance and the report of demands.

Issue #4:

Choosing an ill-fitting system.

Solution:

Your business processes, needs and priorities are unique so a perfect fit does not exist. Your company has to search for a system that fits your needs the most. It is important to have a clear communication with the software vendor. Be upfront about your wishes and priorities and ask for references from the same business sector you operate in. You can exchange experiences with these companies and ask about the features. Can the vendor not give you at least 3 references? Look for another supplier.

Issue #5:

Lack of leadership and engagement of the team.

Solution:

As mentioned, an ERP implementation is an enormous endeavor and means a big change for each employee. Resistance to this change is a common reaction. Strong leadership, creating consensus and engaging employees in the choice of an new ERP system can be very beneficial for the quality of the implementation. The more people are involved in the decision making proces the more they want the implementation to go well and are willing to make an effort.

Set up an implementation team with a team leader that communicates with the vendor and sets out the direction of the project.

Video Content / Details of website for further learning (if any):
https://www.onestein.nl/blog/nieuws-1/post/10-erp-implementation-issues-solutions-18

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :763

LECTURE HANDOUTS

L - 20

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **II- Production Planning and Control and Computerised Process Planning** **Date of Lecture:**

Topic of Lecture: Simple Problems.

Introduction : (Maximum 5 sentences)
ERP stands for **enterprise resource planning**, but what does **ERP** mean? The simplest way to define **ERP** is to think about all the core processes needed to run a company: finance, HR, manufacturing, supply chain, services, procurement, and others.

Prerequisite knowledge for Complete understanding and learning of Topic:
finance, HR, manufacturing, supply chain, services, procurement

Detailed content of the Lecture:

Issue #6:

Not taking advantage of the training offer.

Solution:

The software training vendors offer can be pricey but it will prevent you from a lot of headache after the implementation. Not knowing how to work with the ERP system optimally can cause a diminishing in productivity and a growing annoyance of the users towards the system. Attending a training of the vendor is usually the best choice because this party knows the software thoroughly. The more your team gets into the material, the better the transition to a new ERP system will take place.

Issue #7:

Not looking at the Big Picture.

Solution:

Choosing an ERP system is also a chance to critically look at your business processes and to see if they can be made more efficient. Perhaps the new system has a better inventory tracking or offers the chance to make your workflow more flexible. Be open to change your processes along the choice and implementation of a new ERP system.

Issue #8:

Underestimating needed time and resources.

Solution:

How to estimate the time needed for an ERP implementation? Divide the costs of the software by a 100. For instance, a software system and its implementation costs 20.000 euro. Divided by 100 it means the implementation needs 200 man hours or 5 weeks guided by a professional advisor. Want to do the implementation yourself? Double the man hours.

Issue #9:

An implementation team that is not set up from the beginning of the project and/or does not consist of the right people.

Solution

Many companies are more concerned about the approval of the board than involving the most important people into the implementation team: Finance, Operations, Production, Inventory, Warehouse, IT. In other words, the people that are going to use the system. Get these involved and they sincerely going to work on a well implemented ERP system.

Issue #10:

A multitasking team.

Solution:

Get rid of multitasking and you will diminish delays. People work much slower when they are occupied with various tasks and constantly have to change in pace.

Video Content / Details of website for further learning (if any):
https://www.onestein.nl/blog/nieuws-1/post/10-erp-implementation-issues-solutions-18

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :763

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L - 21

LECTURE HANDOUTS

MECH

Year/Sem : IV / VII

Course Name with Code : Computer Integrated Manufacturing / 16MED25

Course Faculty :

Unit : III- Cellular Manufacturing **Date of Lecture:**

Topic of Lecture: Group Technology (GT)

Introduction : (Maximum 5 sentences)

Group technology or GT is a manufacturing technique in which parts having similarities in geometry, manufacturing process and/or functions are manufactured in one location using a small number of machines or processes.

Prerequisite knowledge for Complete understanding and learning of Topic:

Grouping of parts, design, manufacturing

Detailed content of the Lecture:

Group technology (GT) is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production. Similar parts are arranged into part families. where each part family possesses similar design and/or manufacturing characteristics. for example, a plant producing 10,000 different part numbers may be able 10 group the vast majority of these parts into 30-40 distinct families.

It is reasonable to believe that the processing of each member of a given family is similar. and this should result in manufacturing efficiencies. The efficiencies are generally achieved by arranging the production equipment into machine groups, or cells, to facilitate work flow. Grouping the production equipment into machine cells, where each cell specializes in the production of a part family. is called cellular manufacturing.

These two tasks represent significant obstacles to the application of GT.

1. Identifying the part families. If the plant makes 10,000 different parts, reviewing all of the part drawings and grouping the parts into families is a substantial task that consumes a significant amount of time.

2. Rearranging production machines into machine cells. It is time consuming and costly to plan and accomplish this rearrangement, and the machines are not producing during the changeover.

Group technology offers substantial benefits to companies that have the perseverance to implement it.

The benefits include:

- GT promotes standardization of tooling, fixturing. and setups.
- Material handling is reduced because parts are moved within a machine cell rather than within the entire factory.
- Process planning and production scheduling are simplified
- Setup times are reduced, resulting in lower manufacturing lead times.
- Work-in-process is reduced.
- Worker satisfaction usually improves when workers collaborate in a OT cell.
- Higher quality work is accomplished using group technology.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=8-vVr_F-ZRo

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :508

LECTURE HANDOUTS

L - 22

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Part Families – Parts Classification and coding

Introduction : (Maximum 5 sentences)
The group of similar parts is known as part family and the group of machineries used to process an individual part family is known as machine cell. It is not necessary for each part of a part family to be processed by every machine of corresponding machine cell.

Prerequisite knowledge for Complete understanding and learning of Topic:
Design, manufacturing, parts

Detailed content of the Lecture:

PART FAMILIES
A part family is a collection of parts that are similar either because of geometric shape and size or because similar processing steps are required in their manufacture. The parts within a family are different, but their similarities are close enough to merit their inclusion as members of the part family.

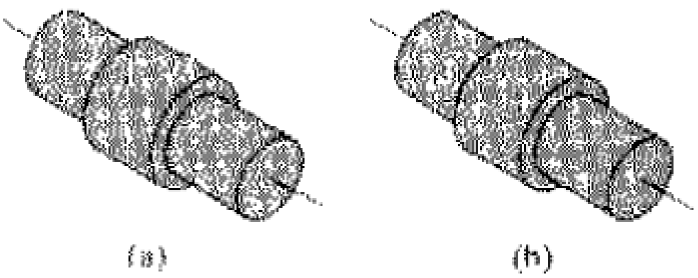


Fig 3.1 Two parts of identical shape and size but different manufacturing requirements: (a) 1.000,pc/yr, tolerance = ±0.0l0in, material = 1015 CR steel, nickel plate; and (b) 100 pc/yr, tolerance = ±*0.001* in, material = 18 - 8 stainless steel.

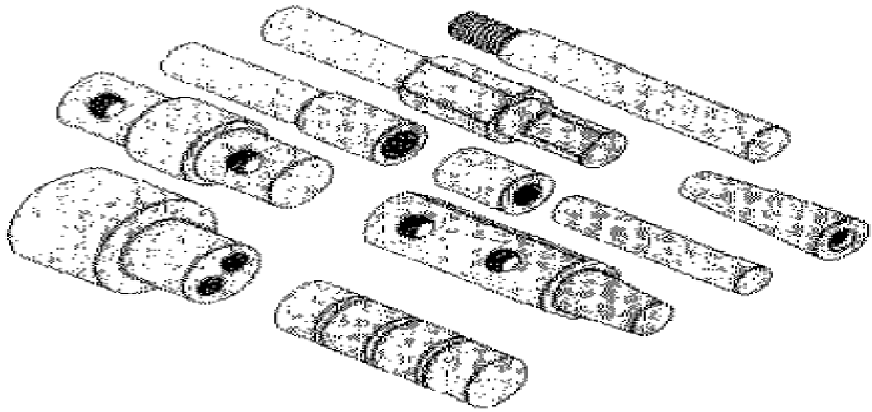


Fig 3.2. A family of parts with similar manufacturing process requirements but different design attributes. All parts are machined from cylindrical stock by turning; some parts require drilling and or milling.

PARTS CLASSIFICATION AND CODING

In parts classification and coding, similarities among parts are identified, and these similarities are related in a coding system. Two categories of part similarities can be distinguished: (1) design attributes, which are concerned with part characteristics such as geometry, size, and material; and (2) manufacturing attributes, which consider the sequence of processing steps required to make a part. While the design and manufacturing attributes of a part are usually correlated, the correction is less than perfect. Accordingly, classification and coding systems are devised to include both a part's design attributes and its manufacturing attributes. Reasons for using a coding scheme include:

- Design retrieval. A designer faced with the task of developing a new part can use a design retrieval system to determine if a similar part already exists. A simple change in an existing part would take much less time than designing a whole new part from scrap
- Automated process planning. The part code for a new part can be used to search for process plans for existing parts with identical or similar codes
- Machine cell design. The part codes can be used to design machine cells capable of producing all members of a particular part family, using the composite part concept

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=eAHIfNaKcVY

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :509-515

LECTURE HANDOUTS

L - 23

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Simple Problems in Opitz Part Coding system

Introduction : (Maximum 5 sentences)

An **Opitz code** is composed of 14 digits divided by three categories. ... **Opitz code** provides a basic framework for under- standing the classification and **coding** process. Further- more, it can be applied to machined **parts**, non-machined **parts** and purchased **parts** as it considers both design and manufacturing information.

Prerequisite knowledge for Complete understanding and learning of Topic:

Group technology, part families, design, manufacturing

Detailed content of the Lecture:

Parts Classification and Coding Systems

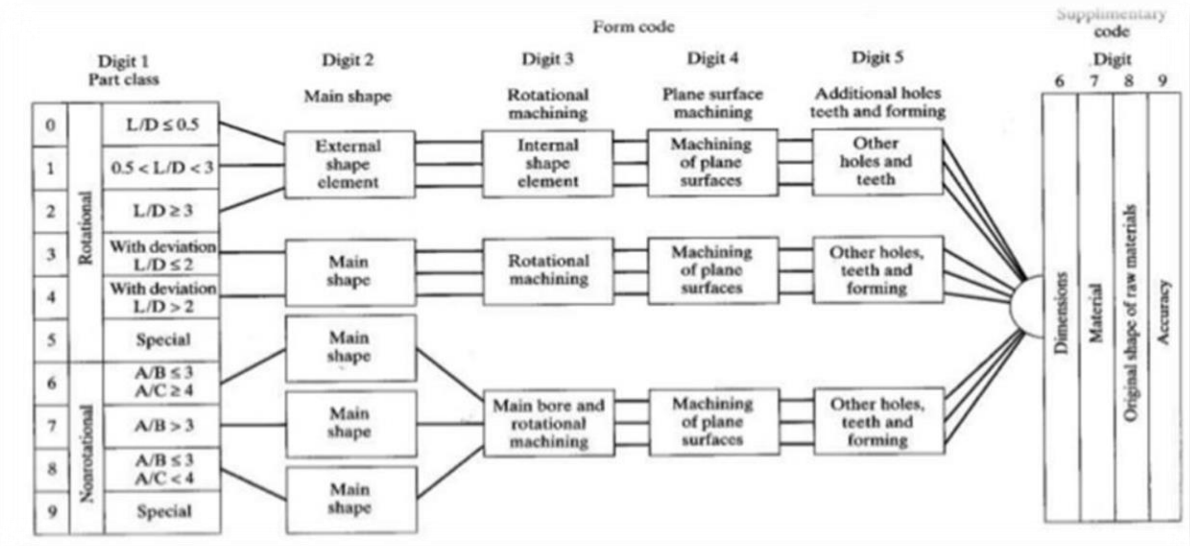
Some of the important systems (with emphasis on those in the United States) include: the

- Opitz classification system, which is non proprietary; the British System ,
- CODE (Manufacturing Data Systems. lnc.]:
- CUTPLAN (Metcut Associates);
- DCLASS (Brigham Young University):
- MultiClass (OIR: Organization for Industrial Research);
- Part Analog System (Lovelace. Lawrence & Co., Inc.).

Opitz Classification System. This system was developed by H. Opitz of the University of Aachen in Germany. It represents one of the pioneering efforts in group technology and is probably the best known, if not the most frequently used, of the parts classification and coding systems. It is intended for machined parts. The Opitz coding scheme uses thc following digit sequence:

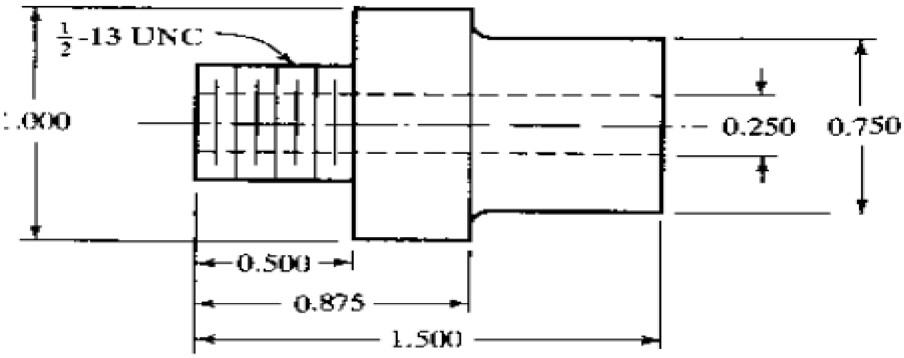
12345 6789 ABCD

The basic code consists of nine digits, which can be extended by adding four more digits. The first nine arc intended to convey both design and manufacturing data. The interpretation of the first nine digits is defined in coding sheet. The first five digits, 12345, are called the form code. It describes the primary design attributes of the part, such as external shape (e.g., rotational vs. rectangular) and machined features (e.g., holes, threads, gear teeth, etc.]. The next four digits, 6789, constitute the supplementary code, which indicates some of the attributes that would be of use in manufacturing (e.g., dimensions, work material, starting shape, and accuracy). The extra four digits,ABCD, are referred to as the secondary code and are intended to identify the production operation type and sequence. The secondary code can be designed by the user firm to serve its own particular needs.



Problem

Given the rotational part design in below Figure, determine the form code in the Opitz parts classification and coding system



With reference to form code for the five-digit code is developed as follows:
Length-to-diameter ratio, *LID* = 1.5 Digit 1 = 1
External shape: stepped on both ends with screw thread on one end Digit 2 = 5
Internal shape: part contains a through-hole Digit 3 == 1
Plane surface machining: none Digit 4 == 0
Auxiliary holes, gear teeth, etc.: none Digit 5 = 0
The form code in the Opitz system is **15100.**

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=06vk0IiTKZo

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :515-516

LECTURE HANDOUTS

L - 24

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Production flow Analysis – Cellular Manufacturing

Introduction : (Maximum 5 sentences)
Production flow analysis (PFA) is a method for identifying part families and associated machine groupings that uses the information contained 011 **production** route sheets rather than on part drawings. Work parts with identical or similar routings are classified into part families.

Prerequisite knowledge for Complete understanding and learning of Topic:
Part families, machine arrangements, layouts

Detailed content of the Lecture:

PRODUCTION FLOW ANALYSIS

Production flow analysis (PFA) is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather than on part drawings. Work parts with identical or similar routings are classified into part families. These families can then be used to form logical machine cells in a group technology layout. Since PFA uses manufacturing data rather than design data to identify part families, it can overcome two possible anomalies that can occur in parts classification and coding. First, parts whose basic geometries are quite different may nevertheless require similar or even identical process routings. Second, parts whose geometries are quite similar may nevertheless require process routings that are quite different.

The procedure in PFA consists of the following steps:

- Data collection. The minimum data needed in the analysis are the part number and operation sequence, which is contained in shop documents called route sheets or operation sheets or some similar name. Each operation is usually associated with a particular machine, so determining the operation sequence also determines the machine sequence. Additional data. such as 101size, time standards, and annual demand might be useful for designing machine cells of the required production capacity.
- Sortation of process routings. In this step, the parts are arranged into groups according to the similarity of their process routings. To facilitate this step, all operations or machines included in the shop are reduced to code numbers. For each part, the operation codes are listed in the order in which they are performed. A sortation procedure is then used to arrange parts into "packs," which are groups of parts with identical routings. Some packs may contain only one part number, indicating the uniqueness of the processing of that part. Other packs will contain many parts, and these will constitute a part family.
- PFA chart. The processes used for each pack are then displayed in a PFA chart, a simplified example of which is illustrated in below The chart is a tabulation of the process or machine code numbers for all of the part packs. In recent GT literature, the PFA chart has been referred to as part-machine incidence

matrix. In this rnatrix, the entries have a value X_{ii} = lor 0: a value of X_{ij} = 1 indicates that the corresponding part i requires processing on machine j, and X'I = 0 indicates that no processing of component i is accomplished on machine j. For clarity of presenting the matrix, the D's are often indicated as blank (empty) entries, as in our table.

- Cluster analysis. From the pattern of data in the PFA chart. related groupings are identified and rearranged into a ncw pattern that brings together packs with similar machine sequences. One possible rearrangement of the original PFA chart is shown below, where different machine groupings are indicated within blocks.

CELLULAR MANUFACTURING

Whether part families have been determined by visual inspection. parts classification and coding, or production flow analysis, there is advantage in producing those parts using group technology machine cells rather than a traditional process-type machine layout. When the machines are grouped. the term cellular manufacturing is used to describe this work organization. Cellular manufacturing is an application of group technology in which dissimilar machines or processes have been aggregated into cells, each of which is dedicated to the production of a part or product family or a limited group of families.

The typical objectives in cellular manufacturing are similar to those of group technology:

• To shorten manufacturing lead times, by reducing setup, work part handling, waiting times, and batch sizes
• To reduce work-in-process inventory. Smaller batch sizes and shorter lead times reduce work-in-process.
• To improve quality. This is accomplished by allowing each cell to specialize in producing a smaller number of different parts. This reduces process variations.
• To simplify production scheduling. The similarity among parts in the family reduces the complexity of production scheduling. Instead of scheduling parts through a sequence of machines in a process-type shop layout, the parts are simply scheduled though the cell.
• To reduce setup times. This is accomplished by using group tooling (cutting tools, jigs, and fixtures) that have been designed to process the part family, rather than part tooling, which is designed for an m dividual part. This reduces the number of individual tools required as well as the time to change tooling between parts.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=dj5h-_Nqc70

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :516-518

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LECTURE HANDOUTS

L - 25

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Composite part concept – Machine cell design and layout

Introduction : (Maximum 5 sentences)

A **composite part** is formed by merging the primitives of all the **parts** of a **part** family. Thus, the **composite** is a single hypothetical **part** that can be completely processed in a manufacturing cell/group. ... The manufacturing facility could be planned on the basis of **composite part** to facilitate economical production.

Prerequisite knowledge for Complete understanding and learning of Topic:

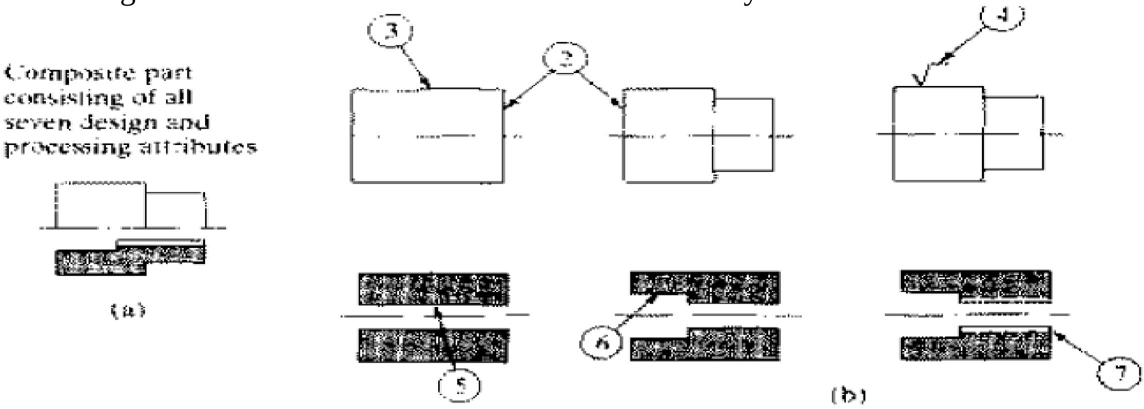
Group technology, design, manufacturing, sequence of operation

Detailed content of the Lecture:

Composite Part Concept

Part families are defined by the fact that their members have similar design and/or manufacturing features. The composite part concept takes this part family definition to its logical conclusion. It conceives of a hypothetical part, a composite part for a given family, which includes all of the design and manufacturing attributes of the family. In general. an individual part in the family will have some of the features that characterize the family but not all of them. The composite part possesses all of the features.

There is always a correlation between part design features and the production operations required to generate those features. Round holes are made by drilling, cylindrical shapes are made by turning, flat surfaces by milling, and so on. A production cell designed for the part family would include those machines required to make the composite part. Such a cell would be capable of producing any member of the family, simply by omitting those operations corresponding to features not possessed by the particular part. The cell would also be designed to allow for size variations within the family as well as feature variations.



Machine Cell Design

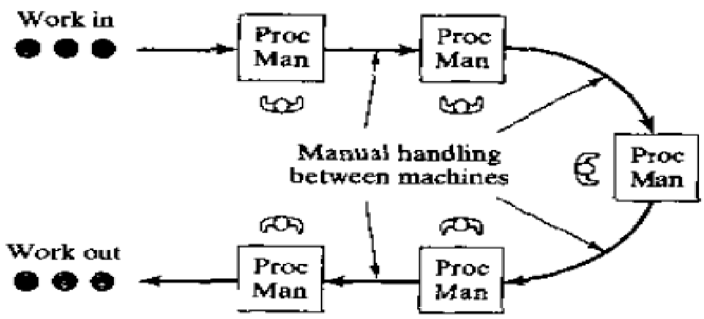
Design of the machine cell is critical in cellular manufacturing. The cell design determines to a great degree the performance of the cell. In this subsection, we discuss types of machine cells, cell layouts, and the key machine concept.

Types of Machine Cells and Layouts. GT manufacturing cells can be classified according to the number of machines and the degree to which the material flow is mechanized between machines. In our classification scheme for manufacturing systems

1. single machine cell (type I M)
2. group machine cell with manual handling (type II M generally, type III M less common)
3. group machine cell with semi-integrated handling (type II M generally, type II M less common)
4. flexibie manufacturing cell or flexible manufacturing system (type II A generally, type III A less common)

the single machine cefl consists of one machine plus supporting fixtures and tooling. This type of cell can be applied to workparts whose attributes allow them to be made on one basic type of process, such as turning or milling. For example, the composite part could be produced on a conventional turret lathe, with the possible exception of the cylindrical grinding operation (step 4) The group machine cell with manual handling is an arrangement of more than one machine used collectively to produce one or more part families. There is no provision for mechanized parts movement between the machines in the cell. Instead, the human operators who run the cell perform the material handling function. The cell is often organized into a U-shaped layout,. This layout is considered appropriate when there is variation in the work flow among the parts made in the cell. It also allows the multifunctional workers in the cell to move easily between machines

The group machine cell with manual handling is sometimes achieved in a conventional process type layout without rearranging the equipment. This is done simply by assigning certain machines to be included in the machine group and restricting their work to specified part families. This allows many of the benefits of cellular manufacturing to be achieved without the expense of rearranging equipment in the shop. Obviously, the material handling benefits of OT are minimized with this organization.



Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=D10VvHlrf6E

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :519-520

LECTURE HANDOUTS **L - 26**

MECH **Year/Sem : IV / VII**

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Quantitative analysis in Cellular Manufacturing

Introduction : (Maximum 5 sentences)
Analysis of a situation or event, especially a financial market, by means of complex mathematical and statistical modelling.

Prerequisite knowledge for Complete understanding and learning of Topic:
Cellular manufacturing, layout, part family

Detailed content of the Lecture:

QUANTITATIVE ANALYSIS IN CELLULAR MANUFACTURING

A number of quantitative techniques have been developed to deal with problem areas in group technology and cellular manufacturing.

Grouping Parts and Machines by Rank Order Clustering

The problem addressed here is to determine how machines in an existing plant should be grouped into machine cells. The problem is the same whether the cells are virtual or formal.It is basically the problem of identifying part families. By identifying part families, the machines required in the cell to produce the part family can be properly selected. As previously discussed, the three basic methods to identify part families are

(1) visual inspection,
(2) parts classification and coding, and
(3) production flow analysis.

The rank order clustering technique. first proposed by King [26J, is specifically applicable in production flow analysis. It is an efficient and easy-to-use algorithm for grouping machines into cells. In a starting part-machine incidence matrix that might be compiled to document the part running in a machine shop (or other job shop), the occupied locations in the matrix are organized in a seemingly random fashion. Rank order clustering works bv reducing the part-machine incidence matrix to a set of diagonalized blocks that represent part families and associated machine groups. Starting with the initial part-machine incidence matrix. the algorithm consist, of the following steps:

1. In each row of the matrix. read the series of ls and G's (blank entries = D's) from left to fight as a binary number. Rank the rows in 01 del uf decreasing value. In case of a tie, rank the rows in the same order as they appear in the current matrix

2. Numbering from top to bottom, is the current order of rows the same as the rank order determined in the previous step? If yes, go to step 7, If no, go to the following step.

3. Reorder the rows in the part-machine incidence matrix by listing them in decreasing rank order, starting from the top

4. In each column to the matrix. read the series of I 's and O's (blank entries = (j's) from top to bottom as a binary number. Rank the columns in order of decreasing value, In case of a tie. rank the columns in the same order as they appear in the current matrix.

5. Numbering from left to right, is the current order of columns the same as the rank order determined in the previous step? If yes. go to step 7. If no.go to the following step.

6. Reorder the columns in the part-machine incidence matrix by li~ling them in decreasing rank order, starting with the left column. Go to step I.

7. Stop

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=X-GcLmE5YoI

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LECTURE HANDOUTS

L - 27

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Rank Order Clustering Method

Introduction : (Maximum 5 sentences)
Rank Order Clustering. Given a binary product-machines n-by-m matrix , **Rank Order Clustering** is an algorithm characterized by the following steps: For each row i compute the number. **Order** rows according to descending numbers previously computed. For each column p compute the number.

Prerequisite knowledge for Complete understanding and learning of Topic:
Production flow analysis, matrix, binary equivalent, cellular manufacturing

Detailed content of the Lecture:
RANK ORDER CLUSTURING TECHNIQUE
Apply the rank order clustering technique to the part-machine incidence matrix in Table

	Parts								
Machines	A	B	C	D	E	F	G	H	I
1	1			1				1	
2					1				1
3			1		1				1
4		1				1			
5	1							1	
6			1						1
7		1				1	1		

Solution:

Step 1 consists 01 reading the series of 1's and D's in each row as a binary number.We have done this in Table IO(a). converting the binary value for each row to its decimal equivalent. The values are then rank ordered in the far right hand column.

Step 2.we see that the row order is different from the starting matrix. We therefore reorder the rows in step 3.

Step 4, we read the series of I's and D's in each column from top to bottom as a binary number (again we have converted to the decimal equivalent], and the columns are ranked in order of decreasing value.

Step 5, we see that the column order is different from the preceding matrix. Proceeding from step 6 back to steps 1 and 2, we see that a reordering of the columns provides a row order that is in descending value. And the algorithm is concluded (step 7). The final solution A close comparison of this solution reveals that they are the carne part-machine groupings.

Final step:

Parts

Machines	A	H	D	B	F	G	I	C	E
1	1	1	1						
5	1	1							
7				1	1	1			
4				1	1				
3							1	1	1
6							1	1	
2							1		1

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=2b_0IZY9Gp0

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :526-528

LECTURE HANDOUTS

L - 28

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Arranging Machines in a GT cell

Introduction : (Maximum 5 sentences)
This type of manufacturing in which a part family is produced by a **machine cell** is known as **cellular** manufacturing. ... **Group technology** is an approach in which similar parts are identified and grouped together in order to take advantage of the similarities in design and production.

Prerequisite knowledge for Complete understanding and learning of Topic:
Design, manufacturing, layout

Detailed content of the Lecture:

Arranging Machines in GT Cell
After part-machine groupings have he en identified hy rank order clustering or other method. the next problem is to organize the machines into the most logical arrangement. Let us describe two simple yet effective methods suggested by Hollier. Both methods use data contained in From-To charts and are intended to arrange the machines in an order that maximizes the proportion of in-sequence moves within the cell
Hollier Method 1. The first method uses the sums of flow "From" and "To" each machine in the cell. The method can be outlined as follows:

- Develop the From-To chart from part routing data. The data contained in the chart indicates numbers of part moves between the machines (or workstations) in the cell. Moves into and out of the cell are not included in the chart.
- Determine the "From" and "To" sums for each machine. This is accomplished by summing all of the "From" trips and "To" trips for each machine (or operation). The "From" sum for a machine is determined by adding the entries in the corresponding row, and the "To" sum is found by adding the entries in the corresponding column.
- Assign machines to the cell hosed on minimum "From" or "To" sums. The machine having the smallest sum is selected. If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence. If the minimum value is a "From" sum, then the machine is placed at the end of the sequence. Tie breaker rules:
- If a tie occurs between minimum "To" sums or minimum "From" sums, then the machine with the minimum "From/To" ratio is selected.
- If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.
- If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and end of the sequence, respectively.

- Reformat the From-To chan. After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding 10 the selected machine and recalculate the "From" and "To" sums. Repeat steps 3 and 4 until all machines have been assigned.

Group Technology Machine Sequence using Hollier Method 1

Suppose that four machines. I, 2.3, and 4 have been identified as belonging in a GT machine cell. An analysis of 50 parts processed on these machines has been summarized in the From-To chart of Table 15.14. Additional information is that '50 parts enter the machine grouping at machine 3,20 parts leave after processing at machine 1, and 30 parts leave after machine 4. Determine a logical machine arrangement using Hollier Method 1.

Solution: Summing the From trips and To trips for each machine yields the "From" and "To" sums in Table 15.15(a). The minimum sum value is the "To" sum for machine 3. Machine 3 is therefore placed at the beginning of the sequence. Eliminating the row and column corresponding to machine 3 yields the revised From-To chart in Table 15.15(b). The minimum sum in this chart is the "To" sum corresponding to machine 2. which is placed at the front at the sequence, immediately following machine 3. Eliminating machine 2 produces the revised From-To chart in Table 15.15(c). The minimum sum in this chart is the "To" sum for machine I. Machine I is placed after machine 2 and finally machine 4 is placed at the end of the sequence. Thus, the resulting machine sequence is

TABLE 15.14 From-To Chart for Example 15.5

	To:	1	2	3	4
From:	1	0	5	0	25
	2	30	0	0	15
	3	10	40	0	0
	4	10	0	0	0

TABLE 15.15(c) From and To Sums for Example 15.5: Third Iteration with Machine 2 Removed

	To:	1	4	"From" Sums
From:	1	0	25	25
	4	10	0	10
"To" sums		10	25	

Video Content / Details of website for further learning (if any):
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Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :528

LECTURE HANDOUTS

L - 29

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **III- Cellular Manufacturing** **Date of Lecture:**

Topic of Lecture: Hollier Method – Simple Problems.

Introduction : (Maximum 5 sentences)
Develop the "From-To" chart from part routing data. The data contained in the chart indicates numbers of parts moves between machines (or work stations) in the cell. Moves into and out of the cell are not included in the chart. Step 2: Determine the "From" and "To" sums for.

Prerequisite knowledge for Complete understanding and learning of Topic:
Rank order clustering, PFA, Part families, GT

Detailed content of the Lecture:

Hollier Method 1.

The first method uses the sums of flow "From" and "To" each machine in the cell. The method can be outlined as follows:

1. Develop the From—To chart from part routing data. The data contained in the chart indicates number of part moves between the machines for workstations)
2. Determine the "From" and "To" sums for each machine. This is accomplished by summing all of the "From" trips and "To" trips for each machine (or operation).The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is found by adding the entries in the corresponding column.
3. Assign machines to the cell based on minimum "From" or To sums. The machine having the smallest sum is selected. If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence. If the minimum value is a "From" sum, then the machine is placed at the end of the sequence. Tie breaker rules:

(a) If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum "From/To" ratio is selected.
(b) If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.
(c) If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

Reformat the From-To chart: After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the "From" and "To" sums. Repeat steps 3 and 4 until all machines have been assigned.

Example 1: Group Technology machine Sequence using Holier Method 1 Suppose that four machines 1, 2, 3, and 4 have been identified as belonging in a GT machine cell. an analysis of 50 parts processed on these machines has been summarized in the From-To chart of Table 2. Additional information is that 50 parts enter
the machine grouping at machine 3, 20 parts leave after processing at machine 1 and 30 parts leave after machine 4. Determine a logical machine arrangement using Hollier Method 1.
Solution: Summing the From trips and To trips for each machine yields the "From" and "To" sums in Table
2(a). The minimum sum value is the "To" sum for machine 3. Machine 3 is therefore placed at the beginning of
the sequence. Eliminating the row and column corresponding to machine 3 yields the revised From To chart in
Table 3 (b).

	To:	1	2	3	4
From:	1	0	5	0	25
	2	30	0	0	15
	3	10	40	0	0
	4	10	0	0	0

Table: 1 From-to chart for example 2

	To:	1	2	3	4	"From" Sums
From:	1	0	5	0	25	30
	2	30	0	0	15	45
	3	10	40	0	0	50
	4	10	0	0	0	10
"To" sums		50	45	0	40	135

	To: 1	2	4	"From" Sums
From: 1	0	5	25	**30**
2	30	0	15	**45**
4	10	0	0	**10**
"To" sums	**40**	**5**	**40**	

Figure: 2.b From and to some example 2:second iteration with machine 3removed

	To: 1	4	"From" Sums
From: 1	0	25	**25**
4	10	0	**10**
"To" sums	**10**	**25**	

Video Content / Details of website for further learning (if any):
https://pit.ac.in/pitnotes/uploads/ME6703_III.pdf

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Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :528

LECTURE HANDOUTS

L - 30

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: Types of Flexibility - FMS

Introduction : (Maximum 5 sentences)

A flexible manufacturing system (FMS) is a production method that is designed to easily adapt to changes in the type and quantity of the product being manufactured. Machines and computerized systems can be configured to manufacture a variety of parts and handle changing levels of production.

Prerequisite knowledge for Complete understanding and learning of Topic:

Manufacturing, mater handling system, process, inspection system.

Detailed content of the Lecture:

Types of Flexibility

Having considered the issue of flexibility and the different types of flexibility that are exhibited by manufacturing systems, let us now, consider the various types of FMSs Shows in table 4.1. Each FMS is designed for a specific application, that is, a specific family of parts and processes Therefore, each FMS is custom engineered; each FMS is unique. Given these circumstances, one would expect to find a great variety of system designs to satisfy a wide variety of application requirements.

Types of Flexibility in Manufacturing. These concepts of Flexibility are not limited to flexible Manufacturing Systems. These concepts of Flexibility are not limited to flexible Manufacturing Systems, they apply to both Manned and Automated systems.

Flexible manufacturing system can be distinguished according to the kinds of operations they perform: (1) Processing operations or (2) Assembly operation. An FMS is usually designed to perform one or the other but rarely both. A difference that is applicable to machining systems in whether the system will process rotational parts or non rotational parts. Flexible machining systems with multiple stations that process rotational parts are much less common that system that process non rotational parts.

Flexibility Type	Definition	Depends on Factors Such As
Machine Flexibility	Capability to adapt a given machine (workstation) in the system to a wide range of production operations and pert styles. The greater the range of operations and part styles, the greater the machine flexibility.	Setup or changeover time Ease of machine reprogramming (ease with which part programs can be downloaded to machines). Tool storage capacity of machines. Skill and versatility of workers in the system.
Production Flexibility	The range or universe of part styles that can be produced on the system.	Machine flexibility of individual stations range of machine flexibilities of all stations in the system.
Mix Flexibility	Ability to change the product mix while maintaining the same total production quantity that is producing the same parts only in different proportions	Similarly of parts in the mix. Relative work content times of parts produced. Machine flexibility
Product flexibility	Case with which design changes can be accommodated. Ease with which new products can be introduced.	How closely the new part design matches the existing part family. Off-line part program preparation. Machine flexibility.
Routing flexibility	Capacity to produce parts through alternative workstation sequences in response to equipment breakdowns tool failures and other interruptions at individual stations.	Similarity of parts in the mix. Similarity of workstations. Duplication of workstations. Cross training of manual workers. Common tooling.
Volume flexibility	Ability to economically produce parts in high and low total quantities of production given the fixed investment in the system.	Level of manual labor performing production. Amount invested in capital equipment.
Expansion flexibility	Ease with which the system can be expanded to increase total production quantities.	Expanse of adding workstations. Ease with which layout can be expanded. Type of part handling system used. Ease with which properly trained workers can be added.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=Fe39k76Ahp8

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LECTURE HANDOUTS

L - 31

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: FMS Components FMS Application & Benefits

Introduction : (Maximum 5 sentences)
The basic components of an FMS are: workstations, material handling and **storage** systems, **computer** control system, and the personnel that manage and operate the system.

Prerequisite knowledge for Complete understanding and learning of Topic:
workstations, material handling and **storage** systems, **computer** control system

Detailed content of the Lecture:

FMS Components
There are four basic components/elements of FMS are

- Workstation
- Material handling and storage system
- Computer control system, and
- Human resources

Workstation
The processing or assembly equipment used in an FMS depends on the type of work accomplished by the system. In a system designed for machining operations, the principle types of processing station are CNC machine tools. However, the FMS concept is also applicable to various other processes as well. Following are the types of workstations typically found in an FMS.

Load/Unload Stations. The load/unload station is the physical interface between the F MS and the rest of the factory. Raw work parts enter the system at this point, and finished parts exit the system from here. Loading and unloading can be accomplished either manually or by automated handling systems. Manual loading and unloading is prevalent in most FMSs today. The load/unload station should be ergonomically designed to permit convenient and safe movement of work parts. For parts that are too heavy to lift by the operator, mechanized cranes and other handling devices are installed to assist the operator. A certain level of cleanliness must be maintained at the workplace. and air hoses or otherwashing facilities are often required to flush away chips and ensure clean mounting and locating points. The station is often raised slightly above floor level using an open-grid platform to permit chips and cutting fluid to drop through the openings for subsequent recycling or disposal. The load/unload station should include a data entry unit and monitor for communication between the operator and the computer system. Instructions must be given to the operator regarding which part to load onto the next pallet to adhere to the production schedule. In cases when different pallets are required for different parts, the correct pallet must be supplied to the station. In cases where modular fixturing is used, the correct fixture must be specified. and the required components and tools must be available at the work station to build it. the handling system must proceed to launch the pallet into the system; however, the handling system must be prevented from moving the pallet while the operator is still working. All of these circumstances require communication between the computer system and the operator at the load/unload station.

Machining stations. The most common applications of FMSs arc machining operations, the workstations used in these systems are therefore predominantly CNC machine tools. Most common is the CNC machining center in particular. the horizontal machining center. CNC machining centers possess features that make them compatible with the FMS, including automatic tool changing and tool storage, use of palletized work parts, CNC, and capacity for distributed numerical control (DNC). Machining centers can be ordered with automatic pallet changers that can be readily interfaced with the FMS part handling system. Machining centers are generally used for non rotational parts. For rotational parts, turning centers are used; and for parts that are mostly rotational but require multitooth rotational cutters (milling and drilling), mill-turn centers can be used.In some machining systems, the types of operations performed are concentrated in a certain category, such as milling or turning. For milling, special milling machine modules can be used to achieve higher production levels than a machining center is capable of. The milling module can be vertical spindle, horizontal spindle, or multiple spindle. **Other Processing Stations.** The FMS concept has been applied to other processing operations in addition to machining. One such application is sheet metal fabrication processes, reported in the processing workstations consist of press working operations, such as punching, shearing, and certain bending and forming processes. Also, flexible systems are being developed to automate the forging process. Forging is traditionally a very labor-intensive operation. The workstations in the system consist principally of a heating furnace, a forging press. and a trimming station.

Assembly. Some FMSs are designed to perform assembly operations. Flexible automated assembly systems are being developed to replace manual labor in the assemblyof products typically made in batches. Industrial robots are often used as the automated workstations in these flexible assembly systems. They can be programmed to perform tasks with variations in sequence and motion pattern to accommodate the different product styles assembled in the system. Other examples of flexible assembly workstations are the programmable component placement machines widely used in electronics assembly.

Other stations and Equipment: inspection can be incorporated into an FMS either by including an inspection operation at a operation at a processing workstation or by including a station specifically designed from inspection. Coordinate measuring machines special inspection probes that can be used in a machine tool spindle and machine vision are three possible technologies for performing inspections on an FMS. Inspection has been found to be particularly important in flexible assembly system to ensure that components have been properly added at the work stations. We examine the topic of automated inspection. These include stations for cleaning parts and/or pallet fixtures central coolant delivery systems for the entire FMS, and centralized chip removal systems often installed below floor level.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=_oiUr2ZBfc8

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :545-557

LECTURE HANDOUTS

L - 32

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: FMS Planning and Control

Introduction : (Maximum 5 sentences)
Implementation of an FMS represents a major investment and commitment by the user company. It is important that the installation *of* the system be preceded by thorough planning and design, and that its operation be characterized by good management of all resources: machines, tools, pallets, parts, and people. Our discussion of these issues is organized along these lines: (1) FMS planning and design issues and (2) FMS operational issues.

Prerequisite knowledge for Complete understanding and learning of Topic:
workstations, material handling and **storage** systems, **computer** control system

Detailed content of the Lecture:

FMS PLANNING AND CONTROL
Explain the FMS Planning and Implanting Issues
Implementation of an FMS represents a major investment and commitment by the user company. It is important that the installation of the system be preceded by thorough planning and design, and that its operation be characterized by good management of all resources machines tools, pallets, parts and people. Our discussions of these issues is organized along these lines:(1) FMS planning and design issues and (2) FMS operational issues.

FMS Planning and Design Issues
The initial phase of FMS planning must consider the parts that will produced by the system. The issues are similar to those in GT machine cell planning. They include:

- Part family considerations. Any FMS must be designed to process a limited range of part (or product) styles. The boundaries of the range must be decided. In effect, the part family that will be processed on the FMS must be defined. The definition of part families to be processed on the FMS can be based on product commonality as well as on part similarity. the term product commonality refers to different components used on the same product. Many successful FMS installations are designed to accommodate part families defined by this criterion. This allows all of the components required to assemble a given product unit to be completed just prior to beginning to assembly.
- Processing requirements. The types of parts and their processing requirements determine the types of processing equipment that will be used in the system. In machining application non rotational parts are produced by machining centres, milling machines and like machine tools rotational parts are machined by turning centres and similar equipment's.
- Physical characteristics of the workparts. The size and weight of the parts determine the size of the machines at the workstations and the size of the material handling system that must be used.
- Production volume. Quantities to be produced by the system determine how many machines will be

required. Production volume is also a factor in selecting the most appropriate type of material handling equipment for the system.

- After the part family production volumes and similar part issues have been decided design of the system can proceed important factors that must be specified in FMS design include:
- **Types of workstations.** The types of machines are determined by part processing requirements. Consideration of workstations must also include the load/unload stations(s).
- **Variations in process routings and FMS layout.** If variation in process sequence are minimal. Then an in-line flow is most appropriate. As product variety increases, loop is more suitable. If there is significant variation in the processing, a ladder layout or open field layout are the most appropriate.
- **Material handling system.** Section of the material handling equipment and layout are closely related. Since the type of handling system limits the layout selection to some extent. The material handling system includes both primary and secondary handling systems.
- **Work in process and storage capacity.** The level of WIP allowed in the FMS is an important variable in determining utilization and efficient of the FMS. If the WIP level is too low then stations may become starved for work, causing reduced utilization. If the WIP level is too high then congestion may result. The WIP level should be planned not just allowed to happen. Storage capacity in the FMS must be compatible with WIP level.
- **Tooling.** Tooling decisions include types and numbers of tools at each station. Consideration should also be given to the degree of duplication of tooling at the different stations. Tool duplication tends to increase routing flexibility.
- **Pallet fixtures.** In machining systems for non rotational parts, the number of pallet fixtures required in the system must be decided. Factors influencing the decision include: levels of WIP allowed in the system and difference in part style and size. Parts that differ too much in configuration and size require different fixturing.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=GpuB0vxCWlI

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :558-560

LECTURE HANDOUTS

L - 33

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: Quantitative analysis in FMS

Introduction : (Maximum 5 sentences)
Most of the design and operational problems identified in Section 16.4 can be addressed using **quantitative analysis** techniques. **FMS analysis** techniques can be classified as follows: (l) deterministic models, (2) queuing models, (3) discrete event simulation, and (4) other approaches, including heuristics

Prerequisite knowledge for Complete understanding and learning of Topic:
Simulation, analysis, mathematical model

Detailed content of the Lecture:

QUANTITATIVE ANALYSIS OF FLEXIBLE MANUFACTURING SYSTEM

Flexible manufacturing systems have constituted an active area of interest in operations research, and many of the important contributions.

FMS analysis techniques can be classified into:

1) Deterministic models,
2) Queuing models,
3) Discrete event simulation, and
4) Other approaches, including heuristics.

1) Deterministic model:

Deterministic models are useful in obtaining starting estimates of system performance. We present a deterministic model that is useful in the beginning stages of FMS design to provide rough estimates of system parameters such as production rate, capacity, and utilization. Deterministic models do not permit evaluation of operating characteristics such as the build-up of queues and other dynamics that can impair system performance. Consequently, deterministic models tend to overestimate FMS performance. On the other hand, if actual system performance is much lower than the estimates provided by these models, it may be a sign of either poor system design or poor management of FMS operations.

2) Queuing Model:

Queuing models can be used to describe some of the dynamics not accounted for in deterministic approaches these models are based on the mathematical theory of queues. They permit the inclusion of queues, but only in a general way and for relatively simple system configurations. The performance measures that are calculated are usually average values for steady-state operation of the system.

3) Discrete Event Simulation:

Model In the later stages of design, discrete event simulation probably offers the most accurate method for modeling the specific aspects of a given flexible manufacturing system [4]. The computer model can be constructed to closely resemble the details of a complex FMS operation. Characteristics such as layout configuration, number of pallets in the system, and production scheduling rules can be incorporated into the FMS simulation model. Indeed, the simulation can be helpful in determining optimum values for these parameters.

BOTTLENECK MODEL AND DRIVE ITS EQUATION.

Important aspects of FMS performance can be mathematically described by a deterministic model called the bottleneck model, developed by Solberg. Although it has the limitations of a deterministic approach, the bottleneck model is simple and intuitive. It can be used to provide starting estimates of FMS design parameters such as production rate, number of workstations, and similar measures. The term bottleneck refers to the fact that the output of the production system has an upper limit, given

that the product mix flowing through the system is fixed. The model can be applied to any production system that possesses this bottleneck feature, for example, a manually operated machine cell or a production job shop. It is not limited to flexible manufacturing systems.

Terminology and Symbols.

Let us define the features, terms, and symbols for the bottleneck model, as they might be applied to a flexible manufacturing system:

- Part mix: The mix of the various part or product styles produced by the system is defined by p_j. where p_j the fraction of the total system output that is of style j. The subscript j= 1,2,…P, where P the number of different part styles made in the FMS during the time period of interest.

$$\sum_{j=1}^{P} p_j = 1.0$$

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=RE_ORuFDOZE

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :560-562

LECTURE HANDOUTS

L - 34

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: Simple Problem

Introduction : (Maximum 5 sentences)
Most of the design and operational **problems** identified in Section 16.4 can be addressed using **quantitative analysis** techniques. **FMS analysis** techniques can be classified as follows: (l) deterministic models, (2) queuing models, (3) discrete event simulation, and (4) other approaches, including heuristics.

Prerequisite knowledge for Complete understanding and learning of Topic:
Analysis, design, FMS, Cell

Detailed content of the Lecture:

A flexible manufacturing cell has just been created. After considering a number of designs, the system engineer chose a layout that consists of two machining workstations plus a load/unload station. In detail, the layout consists of:
The load/unload station is station 1.
Station 2 performs milling operations and consists of one server (one CNC milling machine).
Station 3 has one server that performs drilling (one CNC drill press). The three stations are connected by a part handling system that has one work carrier. The mean transport time in the system is 2.5 min. The FMC produces three parts, A, B, and C.

The part mix fractions and process routings for the three parts are presented in the table below. The operation frequency fijk = 1.0 for all operations. Determine (a) maximum production rate of the FMC, (b) corresponding production rates of each product, (c) utilization of each machine in the system, and (d) number of busy servers at each station.

Part j	Part mix p_j	Operation k	Description	Station i	Process time t_{ijk}
A	0.2	1	Load	1	3 min
		2	Mill	2	20 min
		3	Drill	3	12 min
		4	Unload	1	2 min
B	0.3	1	Load	1	3 min
		2	Mill	2	15 min
		3	Drill	3	30 min
		4	Unload	1	2 min
C	0.5	1	Load	1	3 min
		2	Drill	3	14 min
		3	Mill	2	22 min
		4	Unload	1	2 min

Solution: (a) Use formula to calculate average workload at each station: = ∑ ∑ k ijk ijk j j WLi t f p WL1 = (3+2)(0.2)(1.0) + (3+2)(0.3)(1.0) + (3+2)(0.5)(1.0) = 5.0 min WL2 = 20(0.2)(1.0) + 15(0.3)(1.0) + 22(0.5)(1.0) = 19.5 min WL3 = 12(0.2)(1.0) + 30(0.3)(1.0) + 14(0.5)(1.0) = 18.4 min nt = 3(0.2)(1.0) + 3(0.3)(1.0) + 3(0.5)(1.0) = 3, WL4 = 3(2.5) = 7.5 min

Bottleneck station is determined by formula: is WL = The station with the largest WLi/si ratio is the bottleneck station.

Station	WL_i/s_i ratio	
1 (load/unload)	5.0/1 = 5.0 min	
2 (mill)	19.5/1 = 19.5 min	← Bottleneck
3 (drill)	18.4/1 = 18.4 min	
4 (material handling)	7.5/1 = 7.5 min	

Bottleneck is station 2:

Apply formula:

$$R_p* = \frac{s*}{WL*}$$

R_p* = 1/19.5 = 0.05128 pc/min = **3.077 pc/hr**

(b) Production rates for each product; apply formula for each:

$$R_{pj}* = p_j R_p*$$

R_{pA} = 0.05128(0.2) = 0.01026 pc/min = **0.6154 pc/hr**

R_{pB} = 0.05128(0.3) = 0.01538 pc/min = **0.9231 pc/hr**

R_{pC} = 0.05128(0.5) = 0.02564 pc/min = **1.5385 pc/hr**

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=cQDehLMBaWA

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :563-570

LECTURE HANDOUTS

L – 35

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

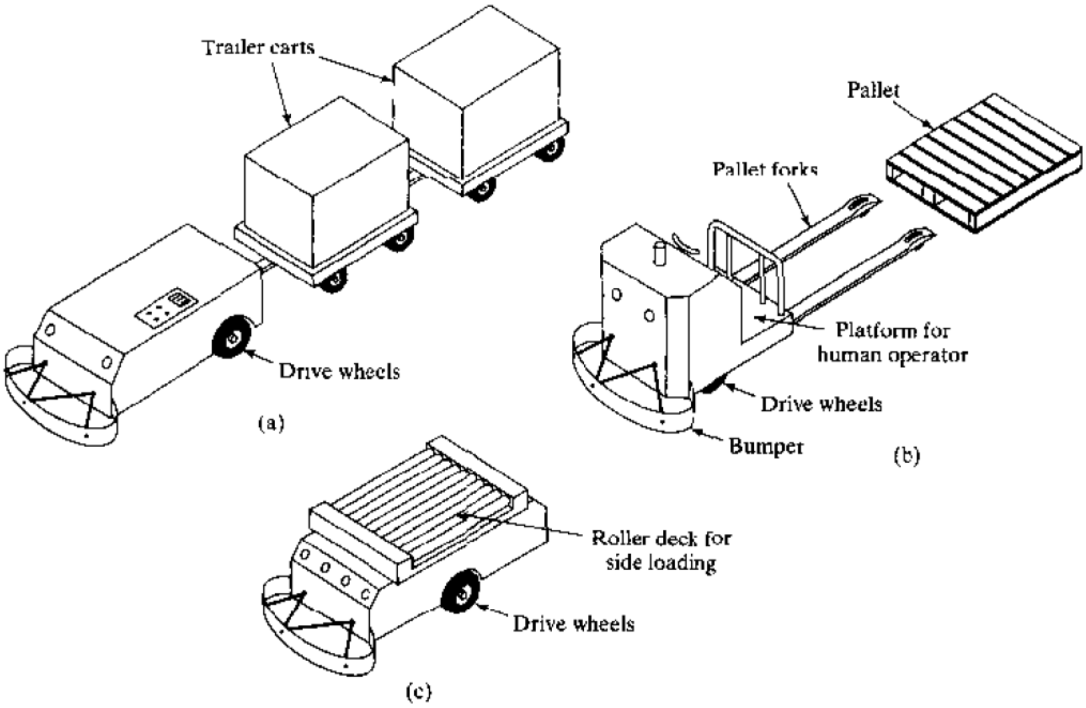
Topic of Lecture: Automated Guided Vehicle System (AGVS) AGVS Application

Introduction : (Maximum 5 sentences)
An automated guided vehicle or automatic guided vehicle (AGV) is a portable robot that follows along marked long lines or wires on the floor, or uses radio waves, vision cameras, magnets, or lasers for navigation. They are most often used in industrial applications to transport heavy materials around a large industrial building, such as a factory or warehouse. Application of the automatic guided vehicle broadened during the late 20th century.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Wired
- Guide tape
- Laser target navigation

Detailed content of the Lecture:
AUTOMATIC GUIDED VEHICLES SYSTEMS (AVGS)
An automated guided vehicle system (AGVS) is a material handling system that uses independently operated, self-propelled vehicles guided along defined pathways. The vehicles arc powered by on-board batteries that allow many hours of operation (8-16 hr is typical) between recharging. A distinguishing feature of an AGVS. compared to rail guided vehicle systems and most conveyor systems, is that the pathways are unobtrusive, An AGVS is appropriate where different materials are moved from various load points to various unload points. An AGVS is therefore suitable for automating material handling in batch production and mixed model production. The first AGV was operated in 1954.
Types of Vehicle and AGVS Applications
Automated guided vehicles can be divided into the following three categories: (1) driverless trains. (2) pallet trucks. and (3) unit load carriers, illustrated in Figure 4.11. A driverless train consists of a towing vehicle (which is the AGV) that pulls one or more trailers to form a train. as in Figure 4.17 (a). It was the first type of AGVS to be introduced and is still widely used today. A common application is moving heavy payloads over large distancesin warehouses or factories with or without intermediate pickup and drop-off points along the route. For trains consisting of five to ten trailers, this is an efficient transport system.



Three types of automated guided vehicles: (a) driverless automated guided train, (b) AGV pallet truck, and (c) unit load carrier.Automated guided pellet trucks. are used to move palletized loads a long predetermined routes. In the typical application the vehicle is backed into the loaded pallet by a human worker who steers the truck and uses its forks to elevate the load slightly. Then the worker drives the pallet truck to the guide path, programs its destination, and the vehicle proceeds automatically to the destination for unloading. The capacity of an AGVS pallet truck ranges up to several thousand kilograms, and some trucks are capable of handling two pallets rather than one.

Light load guided vehicles are designed to move small loads (single parts. small baskets or tole- pans of parts, etc.) through plants of limited size engaged in light manufacturing. An assembly line AGV is designed to carry a partially completed subassembly through a sequence of assembly workstations to build the product.

Automated guided vehicle systems are used in a growing number and variety of applications. The applications tend to parallel the vehicle types previously described. We have already described driverless train operations, which involve the movement of large quantities of material over relatively large distances.

A second application area is in storage and distribution, Unit load carriers and pallet trucks are typically used in these applications. which involve movement of material in unit loads. The applications often interface the AGVS with some other automated handling or storage system. such as an automated storage/retrieval system (AS/RS, Section 4:11) in a distribution center. Electronics assembly is an example of these kinds of applications. Components are "kitted" at the storage area and delivered in tote pans or trays by the guided vehicles to the assembly workstations in the plant. Light load AGVs are the appropriate vehicles in these applications.

Video Content / Details of website for further learning (if any):
https://www.agv.com/de/en/agv/pista-gp-rr-full-face-helmet.html

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page No: 273-284

LECTURE HANDOUTS

L – 36

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: Vehicle Guidance technology

Introduction : (Maximum 5 sentences)
The **vehicle** position is updated using a cross antenna that detects guide wires that are perpendicular to the guide path From these perpendicular guide wires, the controller or supervisor can trace the location of the **AGV**.

Prerequisite knowledge for Complete understanding and learning of Topic:
AGV, Guidance technology, sensor,

Detailed content of the Lecture:

VEHICLE GUIDANCE TECHNOLOGY

The guidance system is the method by which AGVS pathways are defined and vehicles are controlled to follow the pathways. In this section, we discuss three technologies that are used in commercial systems for vehicle guidance: (1) imbedded guide wires, (2) paint strips, and (3)self-guided vehicles.

Imbedded Guide Wires and Paint Strips. In the imbedded guide wire method, electrical wires are placed in a small channel cut into the surface of the floor. The channel is typically .1-12 mm (1/R-l/2 in) wide and 11-26 mm (1/2-1.0 in) deep. After the guide wire is installed, the channel is filled with cement to eliminate the discontinuity in the floor surface. The guide wire is connected to a frequency generator, which emits a low-voltage, low-current signal with a frequency in the range 1-15 kHz. This induces a magnetic field along the pathway that can be followed by sensors on-board each vehicle. The operation of a typical system is illustrated in figure. Two sensors (coils) arc mounted on the vehicle on either side of the guide wire. When the vehicle is located such that the guide wire is directly between the two coils, the intensity of the magnetic field measured by each coil will be equal. If the vehicle strays to one side or the other, or if the guide wire path changes direction, the magnetic field intensity at the two sensors will be different. This difference is used to control the steering motor, which makes the required changes in vehicle direction to equalize the two sensor signals, thereby tracking the guide wire.

A typical AGVS layout contains multiple loops, branches, side tracks, and spurs, as well as pickup and drop-off stations. The most appropriate route must be selected from the alternative pathways available to a vehicle in its movement 10 a specified destination in the system. When a vehicle approaches a branching point where the guide path forks into two (or more) pathways, a means of deciding which path to take must be provided. The two principal methods of making this decision in commercial wire guided systems are: (1) the frequency select method and (2) the path switch select method. In the frequency select method, the guide wires leading into the two separate paths at the switch have different frequencies, As the vehicle enters the switch. it reads an identification code on the floor to determine its location. Depending on its programmed destination, the vehicle selects the correct guide path by following only one of the frequencies; This method requires a separate frequency generator for each different frequency used in the guide path layout. The path switch select method operates with a single frequency throughout the guide path layout. To control the path of a vehicle at a switch, the power is turned off in all other branches except the one that the vehicle is to travel on. To accomplish routing by the path switch select method. The guide path layout is divided into blocks that are electrically insulated from each other. The blocks can he turned on and off either by the vehicles themselves or by a central control computer.

When paint strips are used to define the pathway, the vehicle uses an optical sensor system capable of tracking the paint. The strips can be taped, sprayed, or painted on the floor. One system uses all-in-wide paint strip containing fluorescent particles that reflect an ultraviolet (UV) light source from the vehicle. An on-board sensor detects the reflected light in the strip and controls the steering mechanism to follow it. Paint strip guidance is useful in environments where electrical noise renders the guide wire system unreliable or when the installation of guide wires in the floor surface is not practical. One problem with this guidance method is that the paint strip deteriorates with time. It must be kept clean and periodically repainted.

Self-Guided Vehicles (SGVs) represent the latest AGVS guidance technology. Unlike the previous two guidance methods, SQVs operate without continuously defined pathways. Instead. they use a combination of dead reckoning and beacons located throughout the plant, which can be identified by on-board sensors. Dead reckoning refers to the capability of a vehicle to follow a given route in the absence of a defined pathway in the floor. Movement of the vehicle along the route is accomplished by computing the required number of wheel rotations in a sequence of specified steering angles. The computations are performed by the vehicle's on-board computer. As one would expect, positioning accuracy of dead reckoning decreases with increasing distance. Accordingly, the location of the self-guided vehicle must be periodically verified by comparing the calculated position with one or more known positions. These known positions are established using beacons located strategically throughout the plant. There are various types of beacons used in commercial SOV systems. One system uses bar-coded beacons mounted along the aisles. These beacons can be sensed by a rotating laser scanner on the vehicle. Based on the positions of the beacons, the on-board navigation computer uses triangulation to update the positions calculated by dead reckoning. Another guidance system uses magnetic beacons imbedded in the plant floor along the pathway. Dead reckoning is used to move the vehicle between beacons. and the actual locations of the beacons provide data to update the computer's dead reckoning map.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=3RZP2GJJHu8

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :284-287

LECTURE HANDOUTS

L – 37

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **IV- FMS & AGVs** **Date of Lecture:**

Topic of Lecture: Vehicle Management & Safety

Introduction : (Maximum 5 sentences)
An automated guided vehicle or automatic guided vehicle (AGV) is a portable robot that follows: System management; Vehicle types; Common applications. Most AGV's are equipped with a bumper sensor of some sort as a fail-safe.

Prerequisite knowledge for Complete understanding and learning of Topic:
AGVs, sensor, magnetic tape, applications

Detailed content of the Lecture:

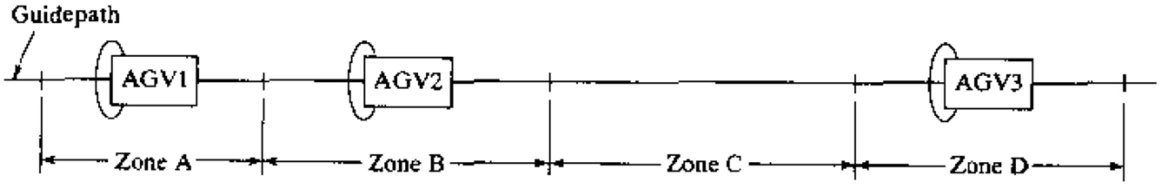
VEHICLE MANAGEMENT AND SAFETY

The AGVS to operate efficiently, the vehicles must be well managed. Delivery tasks must be allocated to vehicles to minimize waiting times at load/unload stations. Traffic congestion in the guide path network must be minimized. And the AGVS must be operated safely. In this section we consider these issues.

Traffic Control. The purpose of traffic control in an automated guided vehicle system is to minimize interference between vehicles and to prevent collisions. Two methods of traffic control used in commercial AGV systems are: (1) on-board vehicle sensing and (2) zone control. The two techniques are often used in combination. On-board vehicle sensing, also called forward sensing, involves the use of one or more sensors on each vehicle to detect the presence of other vehicles and obstacles ahead on the guide path. Sensor technologies include optical and ultrasonic devices. When the on-board sensor detects an obstacle in front of it, the vehicle stops. When the obstacle is removed, the vehicle proceeds. If the sensor system is 100% effective, collisions between vehicles are avoided. The effectiveness of forward sensing is limited by the capability of the sensor to detect obstacles that are in front of it on the guide path. These systems are most effective on straight pathways. They are less effective at turns and convergence points where forward vehicles may not be directly in front of the sensor.

In zone control, the AGVS layout is divided into separate zones, and the operating rule is that no vehicle is permitted to enter a zone if that zone is already occupied by another vehicle. The length of a zone is at least sufficient to hold one vehicle plus allowances for safety and other considerations. Other considerations include number of vehicles in the system, size and complexity of the layout, and the objective of minimizing the number of separate zone controls. For these reasons, the zones are normally much longer than a vehicle length. Zone control is illustrated in Figure 4. 18 in its simplest form. When one vehicle occupies a given zone, any trailing vehicle is not allowed to enter that zone. The leading vehicle must proceed into the next zone before the trailing vehicle can occupy the current zone. By controlling the forward movement of vehicles **in** the separate zones, collisions are prevented, and traffic in the overall system is controlled.

One means of implementing zone control is to use separate control units mounted along the guide path. When a vehicle enters a given zone, it activates the block in that zone to prevent any trailing vehicle from moving forward and colliding with the present vehicle. As the present vehicle moves into the next (downstream) zone, it activates the blockin that 7.00Cand deactivates the block in the previous zone. In effect. zones ate turned on and off to control vehicle movement by the blocking system. Another method to implement zone control is to use a central computer. which monitors the location of each vehicle and attempts to optimize the movement of all vehicles in the system.



Safety. The safety of humans located along the pathway is an important objective in AGVS design; an inherent safety feature of an AGV is that its travelling speed is slower than the normal walking pace of a. human. This minimizes the danger of overtaking a human walking along the guide path in front of the vehicle.In addition. AGVs are usually provided with several other features specifically for safety reasons. A safety feature included in most guidance systems is automatic stopping of the vehicle if it strays more than a short distance, typically 50-150 mm (2-6 in), from the guide path. The distance is referred to as the vehicle's acquisition distance. This automatic stopping feature prevents a vehicle from running wild in the building, Alternatively, in the event that the vehicle is off the guide path (e.g., for loading), its sensor ,system is capable of locking onto the guide path when the vehicle is moved to within the acquisition distance. Another safety device is an obstacle detection sensor located on each vehicle. This is the same on-board sensor used for traffic control. The sensor can detect obstacles along the forward path, including humans. The vehicles are programmed either to stop when an obstacle is sensed ahead or to slow down. The reason for slowing down is that the sensed object may be located off to the side of the vehicle path or directly ahead but beyond a turn in the guide path, or the obstacle may then a person who will move out of the way as the AGV approaches. In any of these cases, the vehicle is permitted to proceed at a slower (safer) speed until it has passed the obstacle.

The disadvantage of programming a vehicle to stop when it encounters an obstacle is that this delays the delivery and degrades system performance. A safety device included on virtually all commercial AGVs is an emergency bumper. This bumper is prominent in several of our figures. The bumper surrounds the front of the vehicle and protrudes ahead 01 it by a distance of 300 mm (12 in) or more. When the bumper makes contact with an object, the vehicle is programmed to brake immediately. Depending on the speed of the vehicle, its load, and other conditions, the braking distance will vary from several inches to several feet. Most vehicles are programmed to require manual restarting after an obstacle has been encountered by the emergency bumper. Other safety devices on a typical vehicle include warning lights (blinking or rotating lights) and/or warning bells, which alert humans that the vehicle is present.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=Rw7D5trwza8

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :286-298

LECTURE HANDOUTS

L – 38

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

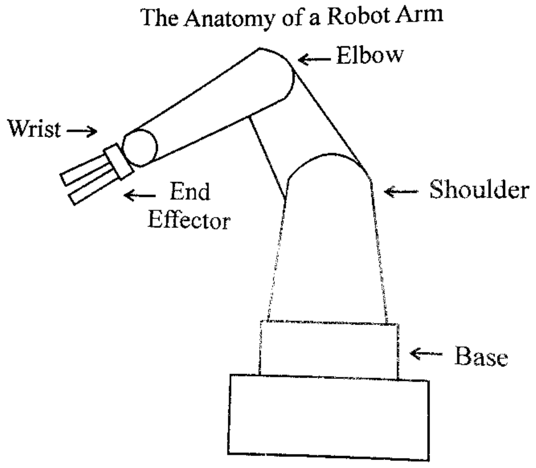
Topic of Lecture: Robot Anatomy and Related Attributes

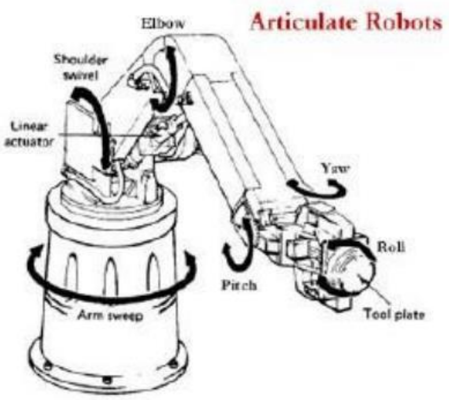
Introduction : (Maximum 5 sentences)
Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of- freedom (dof) of motion.

Prerequisite knowledge for Complete understanding and learning of Topic:
Hazardous environment, fatigue, automation, FMS

Detailed content of the Lecture:

Robot Anatomy:
A robot anatomy is concerned with the physical construction and characteristics of the body, arm and wrist which are the component of the robot manipulator. It is a study of skeleton of robot (or) physical part. It has the following parts.

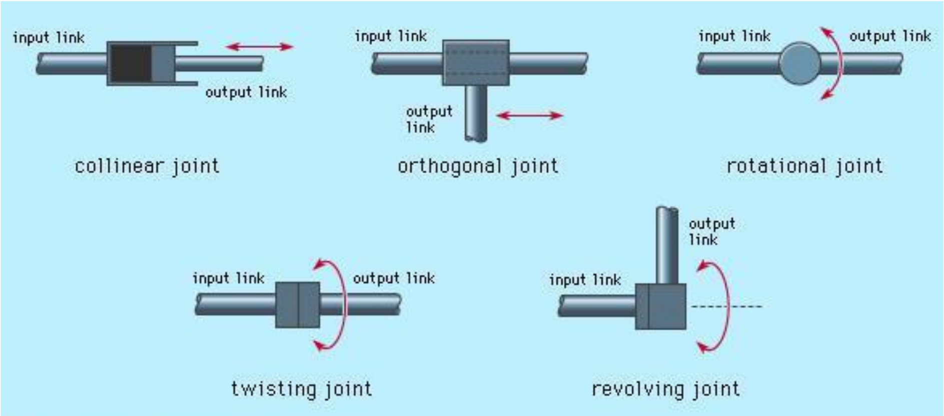




Base - It is the bottom portion of the robot. Mostly it is fixed or movable.
Manipulator- It has arm and wrist. It is also called as assembly of links and joints which has several degrees of freedom. It is used for moving the tools in the work volume and adjust the tools
End-effector or gripper- holding a part/ work piece or tools
Drives or actuators – Causing the manipulator arm or end effector to move in a space.
Controller – with hardware & software support for giving commands to the drives

Sensors - To feed back the information for subsequent action of the arm or grippers as well as to interact with the environment in which the robot is working.
Interface – Connecting the robot subsystem to the external world.
Joints- it is used to connect two links or arms and to perform sliding, rotating, twisting and revolving movements of the arms.
Manipulator Design Requirements

Robot Motions, Links and Joints:- Robot Joints:



Linear joint: Type L joint; the relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links parallel.
Orthogonal joint: Type O joint; the relative movement between the input link and the output link is a translational sliding motion, but the output link is perpendicular to the input link.
Rotational joint: Type R joint; this provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.
Twisting joint: Type T joint; this provides rotary motion, but the axis of rotation is parallel to the axes of the two links
Revolving joint: Type V joint; the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=kLZP0kym2-s

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :215-216

LECTURE HANDOUTS

L – 39

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

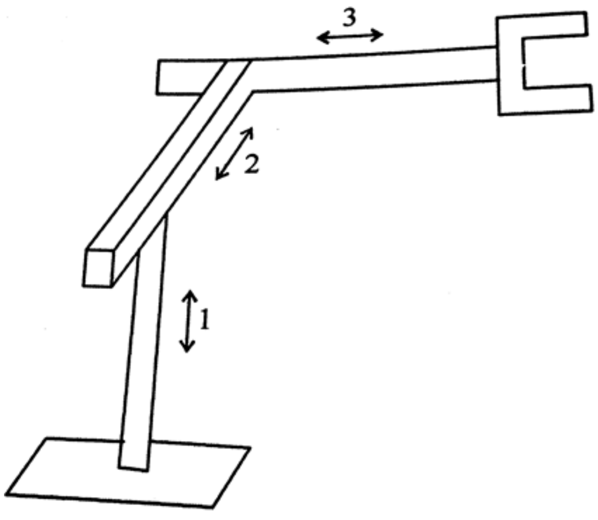
Topic of Lecture: Classification of Robots, Robot Control systems

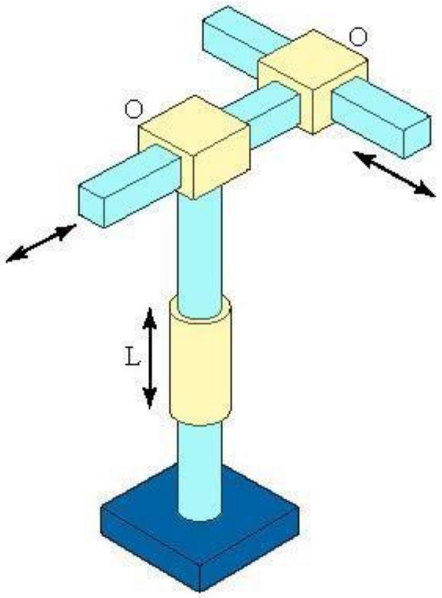
Introduction : (Maximum 5 sentences)
There are two basic **types** of **control systems**: (1) the point-to-point **control system** and (2) the continuous path **control system**. Point-to-point **control system**. With point-to-point **control**, the **robot** records the point where it picks up a part and the point where it releases that part.

Prerequisite knowledge for Complete understanding and learning of Topic:
DOF, Design, construction features, movement

Detailed content of the Lecture:

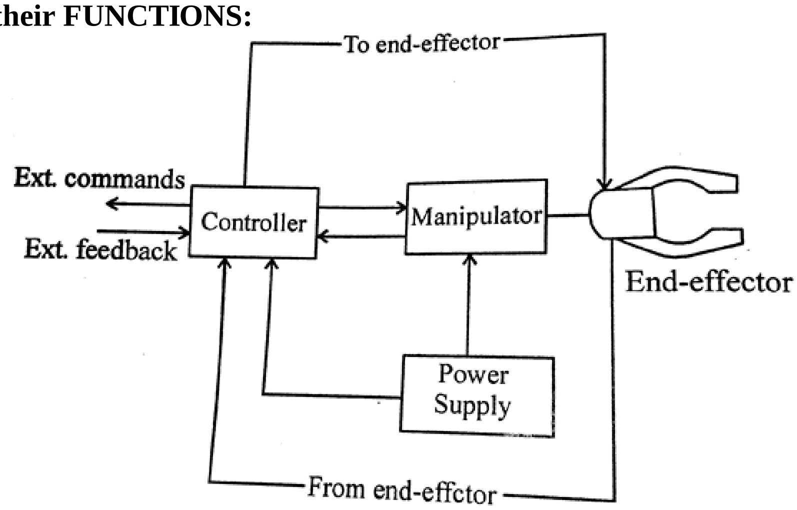
ROBOT CONFIGURATION:
Basically the robot manipulator has two parts viz. a body-and-arm assembly with three degrees-of-freedom; and a wrist assembly with two or three degrees-of-freedom. For body-and-arm configurations, different combinations of joint types are possible for a three-degree-of-freedom robot manipulator. Five common body-and-arm configurations are outlined below
Cartesian configuration

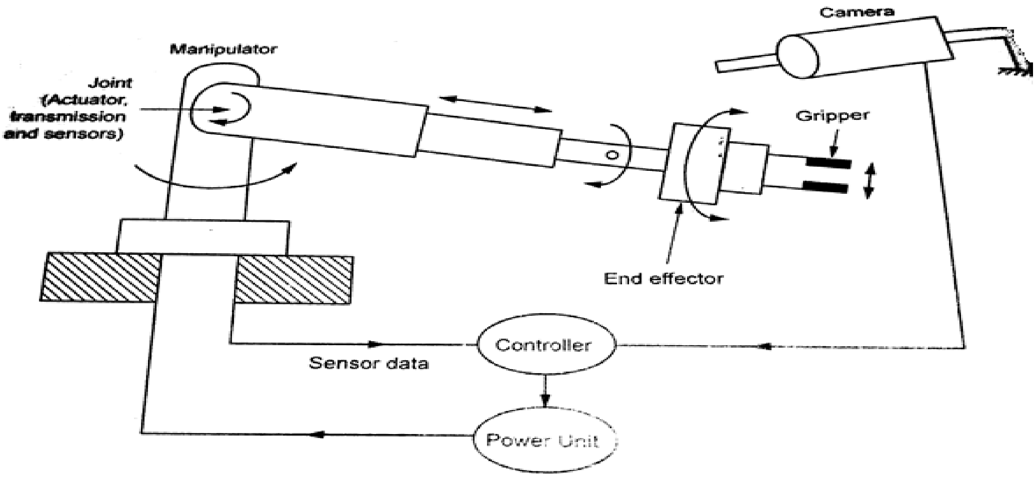




It is also known as rectilinear robot and x-y-z robot. It consists of three sliding joints, two of which are orthogonal O-joints. Cartesian manipulators has 3 perpendicular axes which define a rectangular work volume. Simplest configuration, move in linear, prismatic manner.
Notation: LOO
Advantages: high accurate and speed, less cost, simple operating procedure, high pay loads
Disadvantages: less work envelope, reduced flexibility.
Application: assembly, surface finishing, inspection.
Types: Cantilevered Cartesian, Gantry style
Cantilevered Cartesian – good repeatability, accuracy, less work envelope. Used for light weight loads.
Gantry style Cartesian used for heavy loads less accuracy.

ROBOT PARTS and their FUNCTIONS:





Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=7S8gSScg5Hk

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :217-218

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LECTURE HANDOUTS

L – 40

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: End Effectors

Introduction : (Maximum 5 sentences)
An **end** effector is a peripheral device that attaches to a **robot's** wrist, allowing the **robot** to interact with its task. Most **end effectors** are mechanical or electromechanical and serve as grippers, process tools, or sensors

Prerequisite knowledge for Complete understanding and learning of Topic:
Material handling, design, movement of parts

Detailed content of the Lecture:

End effectors arc devices that, although they are attached to the wrist of the manipulator. It is actuated very much like external devices. Special commands are usually written for controlling the end effector. In the case of grippers, the basic commands are

OPEN

and

CLOSE

which came the gripper to actuate to fully open and fully closed positions, respectively. Greater control over the gripper is available in some sensored and servo-controlled hands.

For grippers that have force sensors that can be regulated through the robot controller, a command such as

CLOSE2.0N

Controls the dosing of the gripper until a 2.0N force is encountered by the gripper fingers. A similar command used \0 close the gripper to a given opening width is:

CLOSE25MM

A special set of statements is often required to control the operation of tool-type end effectors, such as spot welding guns, arc welding tools, spray painting guns, and powered spindles (for drilling, grinding, etc.]. Spot welding and spray painting controls are typically simple binary commands (e.g., open/close and on/off), and these commands would be similar to those used for gripper control. In the case of arc welding and powered spindles, a greater variety of control statements is needed to control feed rates and other parameters of the operation

Computations and Program Logic. Many of the current generation robot languages possess capabilities for performing computations and data processing operations that are similar to computer programming languages. Most present-day robot applications do not require a high level of computational power. As the complexity of robot applications grows in the future, it is expected that these capabilities will be better utilized than at present, Many of today's applications of robots require the use of branches and subroutines in the program.

Statements such as
GOTO 150
And
IF (logical expression) GO TO 150
Cause tile program TO branch to some other statement in the program [e.g., to statement number 150 in the above illustrations).

A subroutine in a robot program is a group of statements that are to be executed separately when called from the main program. In a preceding example, the subroutine SAFESTOP was named in the REACT statement for use in safety monitoring. Other uses of subroutines include making calculations or performing repetitive motion sequences at a number of different places in the program. Rather than write the same steps several times in the program, the use of a subroutine is more efficient.

End Effector: This is the part that generally handles objects, makes connection to other machines, or performs the required tasks. It can vary in size and complexity from end -effector on the space shuttle to a small gripper. The end-effector is the "hand" connected to the robot's arm. It is often different from a human hand - it could be a tool such as a gripper, a vacuum pump, tweezers, scalpel, blowtorch - just about anything that helps it do its job. Some robots can change end-effectors, and be reprogrammed for a different set of tasks.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=sr_q_crQBQE

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :223-224

LECTURE HANDOUTS

L – 41

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: Sensors in Robotics

Introduction : (Maximum 5 sentences)
A **sensor** is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A **sensor** is always used with other electronics.

Prerequisite knowledge for Complete understanding and learning of Topic:
Electronics, physical variables,

Detailed content of the Lecture:

A sensor acquires a physical quantity and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)

- Nowadays common sensors convert measurement of physical phenomena into an electrical signal
- Active element of a sensor is called a transducer

Transducer - A device which converts one form of energy to another When input is a physical quantity and output electrical → Sensor When input is electrical and output a physical quantity → Actuator

Commonly Detectable Phenomena •Biological •Chemical •Electric •Electromagnetic •Heat/Temperature •Magnetic •Mechanical motion (displacement, velocity, acceleration, etc.) •Optical •Radioactivity

Common Conversion Methods •Physical –thermo-electric, thermo-elastic, thermo-magnetic, thermo-optic –photo-electric, photo-elastic, photo-magnetic, –electro-elastic, electro-magnetic –magneto-electric •Chemical –chemical transport, physical transformation, electro-chemical •Biological –biological transformation, physical transformation

Physical Principles: Examples

- Amperes's Law – A current carrying conductor in a magnetic field experiences a force (e.g. galvanometer)
- Curie-Weiss Law – There is a transition temperature at which ferromagnetic materials exhibit paramagnetic behavior
- Faraday's Law of Induction – A coil resist a change in magnetic field by generating an opposing

voltage/current (e.g. transformer) • Photoconductive Effect – When light strikes certain semiconductor materials, the resistance of the material decreases (e.g. photoresistor)

Stimulus	Quantity
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave Velocity
Biological & Chemical	Fluid Concentrations (Gas or Liquid)
Electric	Charge, Voltage, Current, Electric Field (amplitude, phase, polarization), Conductivity, Permittivity
Magnetic	Magnetic Field (amplitude, phase, polarization), Flux, Permeability
Optical	Refractive Index, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific Heat, Thermal Conductivity
Mechanical	Position, Velocity, Acceleration, Force, Strain, Stress, Pressure, Torque

Choosing a Sensor

Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Video Content / Details of website for further learning (if any):
http://engineering.nyu.edu/gk12/amps-cbri/pdf/Intro%20to%20Sensors.pdf

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :224-225

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Estd. 2000

LECTURE HANDOUTS

L – 42

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: Robot Accuracy and Repeatability

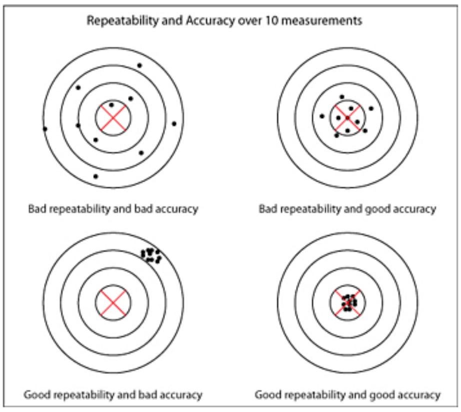
Introduction : (Maximum 5 sentences)

Accuracy – is how closely a robot can reach a commanded position. When the absolute position of the robot is measured and compared to the commanded position the error is a measure of accuracy. Accuracy can be improved with external sensing for example a vision system or Infra-Red
The **repeatability** of a **robot** might be defined as its ability to achieve repetition of the same task. On the other hand, **accuracy** is the difference (i.e. the error) between the requested task and the obtained task (i.e. the task actually achieved by the **robot**).

Prerequisite knowledge for Complete understanding and learning of Topic:
Application of robots, accuracy, precision, continuous operation

Detailed content of the Lecture:

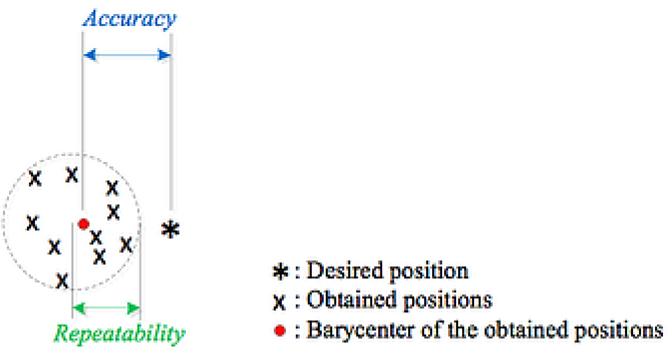
An industrial robot has many metrology or measurable characteristics, which will have a direct impact on the effectiveness of the robot during the execution of its tasks. The main measurable characteristics are repeatability and accuracy. Roughly speaking, the repeatability of a robot might be defined as its ability to achieve repetition of the same task. On the other hand, accuracy is the difference (i.e. the error) between the requested task and the obtained task (i.e. the task actually achieved by the robot). In robotics, when talking about repeatability and accuracy, their meanings are often confused. So, repeatability is doing the same task over and over again, while accuracy is hitting your target each time.



First, let's introduce the main characteristics of a robot whose repeatability and accuracy are likely to be important to evaluate: path, position and orientation. These are the factors that you want to assure you are achieving each and every time you set your robot and end-effector in motion. The combination of position and orientation with the robot's end-effector is called a pose. Furthermore, the pose accuracy generally will have some effect on the path accuracy, which because of its inherent movement is a dynamic characteristic. However, in order to avoid confusion in this short paper, we will focus on static characteristics without considering motion effects. Therefore, only the pose accuracy and repeatability will be discussed. The pose accuracy and repeatability of the robot are divided into the two previously mentioned components: position and orientation. To simplify even further, the following explanations are set forth describing position only, though they can be extended to orientation as well.

The absolute position accuracy is the ability of the robot to reach a specific programmed position with a minimum of error. Note that here we use the word absolute to refer to the fact that the position accuracy is evaluated with respect to a unique reference frame, mainly the work reference frame (or the world reference frame). Often these are arbitrary frames of reference used specifically to measure the variations in position accuracy. To assess the static accuracy of the robot movement, the position measurements are carried out after a complete stop of the end-effector's movement (regardless of the path taken to reach the desired position) from the previous pose of the end-effector.

Geometrically, the position accuracy of the robot for a given position can be defined as being the distance between the desired position and the centroid position (centroid is the mean position of all the points in all of the coordinate directions) which is actually achieved after repetitive movements of the end-effector toward the original desired position (see the Figure below). Mathematically, absolute accuracy is the compilation of the composed errors for each of the x, y, z cartesian positional errors. Finally, the robot position accuracy for a specific workspace can be described as the maximum composed error available for several positions uniformly distributed inside the predetermined workspace or reference frame.



Video Content / Details of website for further learning (if any):
https://blog.robotiq.com/bid/72766/What-are-Accuracy-and-Repeatability-in-Industrial-Robots

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :241

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LECTURE HANDOUTS

L – 43

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: Industrial Robot Applications

Introduction : (Maximum 5 sentences)

The programmability of industrial robots was largely a tool that could allow them to be used for a variety of different tasks, but it didn't really give them intelligence. They completed monotonous and unsafe tasks and were deployed for their precision and repeatability. As a result, the automotive industry has been the most important customer of industrial robots

Prerequisite knowledge for Complete understanding and learning of Topic:
Automation, accuracy, precision, hazardous environment

Detailed content of the Lecture:

Application	Degrees of Freedom	Structure	Drive system	Program	Nature of Task	Control systems
Material Handling	3-5	Jointed Adaptable Robot arm	Servo motors	Programmable Automation Control (PAC)	Safe/hazardo Rus Complicated	Motion Controllers with Sensor Technology.
Part loading and unloading	4-5 Multiple arms	Polar, Cylindrical Jointed arm (Adoptable)	Electronic Servo Motors (For heavy loads)	Programmable Automation Control (PAC)	Complicated and safe environments	Micro controller and Motion Controller with vision.
Spot welding	5-6	Polar Jointed adaptable robotic arm	Electronic Stepper motors	Programmable logic Controllers (PLC)	Simple and safe	Microcontroller with Changeable functions
Arc Welding	5-6	Polar modular Cartesian with adaptable jointed arm	Direct drive servo motors	Programmable Automation and Control	Complicated and unsafe	Continuous path motion controllers with sensor Technology.

Spray Coating	6 or more	Jointed arm with adoptable gun	Hydraulic Actuators	Programmable automation control with controller area Network	Simple and unsafe	Continuous path motion controllers
Electronic Assembly	3-6 Multiple arms coupled motion	Jointed adaptable, Cartesian modular robotic arm	Stepper motors and direct Drives	Programmable automation control with controller area Network	Complicated and safe	Microcontroller, nodes with sensors and end effectors with vision systems.
Automobile Assembly	3-6 Multiple arms coupled motion	Jointed arm Cartesian SCARA	Electrical and powered lead through	Programmable automation control with controller area Network	Complicated and safe	Microcontroller, nodes with sensors and end effectors with vision systems

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=lR7c2rEFOH0

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :225-232

LECTURE HANDOUTS

L – 44

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: Robot Part Programming

Introduction : (Maximum 5 sentences)
Robot software is the set of coded commands or instructions that tell a mechanical device and electronic system, known together as a **robot**, what tasks to perform. **Robot** software is used to perform autonomous tasks. Many software systems and frameworks have been proposed to make **programming robots** easier.

Prerequisite knowledge for Complete understanding and learning of Topic:
Control, drive system, applications

Detailed content of the Lecture:

ROBOT PROGRAMMING

To do useful work, a robot must be programmed to perform its motion cycle. A robot program can be defined as a path in space10be followed by the manipulator, combined with peripheral actions that support the work cycle, Examples of the peripheral actions include opening and closing the gripper, performing logical decision making, and communicating with other pieces of equipment in the robot cell. A robot is programmed by entering the
Programming commands into its controller memory. Different robots use different methods of entering the commands.

In the case of limited sequence robots, programming is accomplished by setting limit switches and mechanical stops to control the endpoints of its motions. The sequence in which the motion occurs is regulated by a sequencing device. The device determines the order in which each joint is actuated to form the complete motion cycle. Setting the stops and switches and wiring sequence is more manual setup than part programming. today and in the foreseeable future nearly all industrial robots have digital computers aas their controllers, together with compatabile storage devices as their memory units for these robots three programming method can be distinguished: (1) Lead through programming (2) Computer like robot programming language (3) offline programming.

Lead through Programming and robot language programming are the two methods most commonly used today for entering the commands into computer memory. in lead through programming the task is taught to the robot by moving the manipulator through the required motion cycle, simultaneously entering the program into the controller memory for subsequent playback.

Powered Lead through Versus Manual Leadthrough. There are two methodsof performing the leadthrough teach procedure: (1) powered leadthrough and (2) manual lead through. The difference between the two is in the manner in which the manipulator is moved through the motion cycle during programming. Powered leadthrough is commonly used a~ the programming method for playback robots with point-to-point control. It in· valves the use of J teach pendant (handheld control box) that has toggle switches and/or contact buttons for controlling the movement of the manipulator joints. Figure 7.13 illustrates the important components of a teach pendant. Using the toggle switches or buttons, the programmer power drives the robot arm to the desired positions, in sequence, and records the positions into memory. During subsequent playback, the robot moves through the sequence 01 positions under its own power.

Manual leadthrough is convenient for programming playback robots with continuous path control where the continuous path is an irregular motion pattern such as in spray painting. This programming method requires the operator to physically grasp the end-of-arm or tool attached to the arm and manually move it through the motion sequence, recording the path into memory. Because the robot arm itself may have significant mass and would therefore he difficult to move, a special programming device often replaces the actual robot for the teach procedure. The programming device has the same joint configuration as the robot. and it is equipped with a trigger handle (or other control switch), which is activated when the operator wishes to record motions into memory. The motions arc recorded a~ a series of closely spaced points' During playback, the path is recreated by controlling the actual robot arm through the same sequence of points.

Motion Programming. The lendthrough methods provide a very natural way of programming motion commands into the robot controller. In manual leadthrough, the operator simply moves the arm through the required path to create the program. In powered leadthrough the operator uses a teach pendant to drive the manipulator. The teach pen b equipped with switch or a pair of contact buttons for each joint By activating these switches or in a coordinated fashion for the various joints. The programmer moves the manipulator to The required positions in the work space.

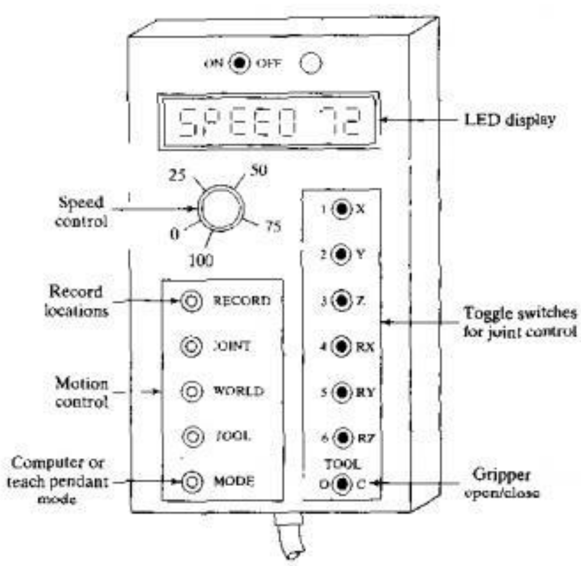

Figure 7.13 A typical robot teach pendant.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=qA9w-ILWwWI

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :233-236

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LECTURE HANDOUTS

L – 45

MECH

Year/Sem : IV / VII

Course Name with Code : **Computer Integrated Manufacturing / 16MED25**

Course Faculty :

Unit : **V- Industrial Robotics** **Date of Lecture:**

Topic of Lecture: Simple problems

Introduction : (Maximum 5 sentences)
Robot software is the set of coded commands or instructions that tell a mechanical device and electronic system, known together as a **robot**, what tasks to perform. **Robot** software is used to perform autonomous tasks. Many software systems and frameworks have been proposed to make **programming robots** easier.

Prerequisite knowledge for Complete understanding and learning of Topic:
Control, drive system, applications

Detailed content of the Lecture:

Simple program to pick and place objects

```
#include <evive.h>

double angle_rad = PI/180.0;
double angle_deg = 180.0/PI;
double BaseServoAngle;
double Link1ServoAngle;
double VariableVoltage;
TFT_ST7735 lcd = TFT_ST7735();
Servo servo_44;
Servo servo_45;
Servo servo_9;
Servo servo_10;

void setup(){
   lcd.init(INITR_BLACKTAB);
   lcd.setRotation(1);
   lcd.fillScreen(0);

   pinMode(A0+9,INPUT);
   servo_44.attach(44); // init pin
```

```
  pinMode(A0+10,INPUT);
  servo_45.attach(45); // init pin
  pinMode(40,INPUT);
  servo_9.attach(9); // init pin
  pinMode(41,INPUT);
  pinMode(42,INPUT);
  servo_10.attach(10); // init pin
  pinMode(A0+7,INPUT);
}

void loop(){
  BaseServoAngle = analogRead(A0+9);
  BaseServoAngle = ((BaseServoAngle) * (180)) / (1023);
  BaseServoAngle = (180) - (BaseServoAngle);
  servo_44.write(BaseServoAngle); // write to servo
  Link1ServoAngle = analogRead(A0+10);
  Link1ServoAngle = ((Link1ServoAngle) * (180)) / (1023);
  Link1ServoAngle = (180) - (Link1ServoAngle);
  servo_45.write(Link1ServoAngle); // write to servo
  if(digitalRead(40)){
    servo_9.write(180); // write to servo
    lcd.setCursor(10, 55);
    lcd.print("Gripper Up        ");
  }else{
    if(digitalRead(41)){
      servo_9.write(0); // write to servo
      lcd.setCursor(10, 55);
      lcd.print("Gripper Down      ");
    }else{
      servo_9.write(90); // write to servo
      lcd.setCursor(10, 55);
      lcd.print("Gripper Straight  ");
    }
  }
  if(digitalRead(42)){
    servo_10.write(90); // write to servo
    lcd.setCursor(10, 70);
    lcd.print("Gripper Open ");
  }else{
    servo_10.write(0); // write to servo
    lcd.setCursor(10, 70);
    lcd.print("Gripper Close");
  }
  VariableVoltage = analogRead(A0+7);
  VariableVoltage = (VariableVoltage) * (0.0381);
  lcd.setCursor(10, 10);
  lcd.print("Voltage: ");
  lcd.print(VariableVoltage);
  lcd.print(" V   ");
  lcd.setCursor(10, 25);
  lcd.print("Base Servo: ");
  lcd.print(BaseServoAngle);
```

```
lcd.print(" Deg   ");
lcd.setCursor(10, 40);
```

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=0ygOIxj1Ko0

Important Books/Journals for further learning including the page nos.:

Mikell.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, Pearson Education, Limited, 2015 Page No. :237-240