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G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY

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Department of Mechanical Engineering

Bridge Course
On
Automation & Robotics

Industrial engineering

Industrial engineering is a branch of engineering which deals with the optimization of complex processes, systems or organizations. Industrial engineers work to eliminate waste of time, money, materials, man-hours, machine time, energy and other resources that do not generate value. According to the Institute of Industrial and Systems Engineers, they figure out how to do things better, engineering processes and systems that improve quality and productivity.

Industrial engineering is concerned with the development, improvement, and implementation of integrated systems of people, money, knowledge, information, equipment, energy, materials, analysis and synthesis, as well as the mathematical, physical and social sciences together with the principles and methods of engineering design to specify, predict, and evaluate the results to be obtained from such systems or processes. While industrial engineering is a longstanding engineering discipline subject to (and eligible for) professional engineering licensure in most jurisdictions, its underlying concepts overlap considerably with certain business-oriented disciplines such as operations management.

While originally applied to manufacturing, the use of "industrial" in "industrial engineering" can be somewhat misleading, since it has grown to encompass any methodical or quantitative approach to optimizing how a process, system, or organization operates. Some engineering universities and educational agencies around the world have changed the term "industrial" to broader terms such as "production" or "systems", leading to the typical extensions noted above.

The various topics concerning industrial engineers include:

1. **Process engineering**: design, operation, control, and optimization of chemical, physical, and biological Processes.
2. **Systems engineering**: an interdisciplinary field of engineering that focuses on how to design and manage complex engineering systems over their life cycles.
3. **Safety engineering:** an engineering discipline which assures that engineered systems provide acceptable levels of safety.
4. **Data science:** the science of exploring, manipulating, analyzing, and visualizing data to derive useful insights and conclusions
5. **Machine learning:** the automation of learning from data using models and algorithms
6. **Analytics and data mining:** the discovery, interpretation, and extraction of patterns and insights from large quantities of data
7. **Cost engineering:** practice devoted to the management of project cost, involving such activities as cost- and control- estimating, which cost control and cost is forecasting, investment appraisal, and risk analysis.
8. **Value engineering:** a systematic method to improve the "value" of goods or products and services by using an examination of function.
9. **Quality engineering:** a way of preventing mistakes or defects in manufactured products and avoiding

problems when delivering solutions or services to customers.

10. **Project management:** is the process and activity of planning, organizing, motivating, and controlling resources, procedures and protocols to achieve specific goals in scientific or daily problems.
11. **Management engineering:** a specialized form of management that is concerned with the application of engineering principles to business practice.
12. **Supply chain management:** the management of the flow of goods. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption.
13. **Ergonomics:** the practice of designing products, systems or processes to take proper account of the interaction between them and the people that use them.
14. **Operations research, also known as management science:** discipline that deals with the application of advanced analytical methods to help make better decisions
15. **Operations management:** an area of management concerned with overseeing, designing, and controlling the process of production and redesigning business operations in the production of goods or services.
16. **Job design:** the specification of contents, methods and relationship of jobs in order to satisfy technological and organizational requirements as well as the social and personal requirements of the job holder.
17. **Financial engineering:** the application of technical methods, especially from mathematical finance and computational finance, in the practice of finance
18. **Industrial plant configuration:** sizing of necessary infrastructure used in support and maintenance of a given facility.
19. **Facility management:** an interdisciplinary field devoted to the coordination of space, infrastructure, people and organization
20. **Engineering design process:** formulation of a plan to help an engineer build a product with a specified performance goal.
21. **Logistics:** the management of the flow of goods between the point of origin and the point of consumption in order to meet some requirements, of customers or corporations.
22. **Accounting:** the measurement, processing and communication of financial information about Economic entities
23. **Capital projects:** the management of activities in capital projects involves the flow of resources, or inputs, as they are transformed into outputs. Many of the tools and principles of Industrial Engineering can be applied to the configuration of work activities within a project. The application of industrial engineering and operations management concepts and techniques to the execution of projects has been thus referred to as Project Production Management.

Traditionally, a major aspect of industrial engineering was planning the layouts of factories and designing assembly lines and other manufacturing paradigms. And now, in lean manufacturing systems, industrial engineers work to eliminate wastes of time, money, materials, energy, and other resources. Depending on the sub-specialties involved, industrial engineering may also be known as, or overlap with, operations research, systems engineering, manufacturing engineering, production engineering, management science, management engineering, ergonomics or human factors engineering, safety engineering, or others, depending on the viewpoint or motives of the user.

Scheduling

Definition of Scheduling

Scheduling deals with the efficient allocation of tasks over resources. The general scheduling problem is, given a number of tasks and a number of resources, set the dates when each task should be accomplished on each resource. We are interested in scheduling in the manufacturing context, although it has many applications in other fields.

Real-life examples

1. Timetabling
2. Scheduling of the PC room at Duisburg University: a number of different courses (tasks) have to be given using the PC room (resource)
3. Workforce scheduling
4. Assign shifts for nurses and doctors in a Hospital
5. Sports scheduling

Introduction to production scheduling:

1. Scheduling
2. Production scheduling
3. Gantt Chart
4. Scheduling environment
5. Constraints
6. Scheduling objectives

The MRP tell us the quantities of products to manufacture in every time bucket However, MRP does not make any assumption about the resources (i.e. labour, machines) currently available in the factory.

E.g. two different components have to be manufactured in the same section. How to schedule them? Therefore, we have a number of jobs (j) to be manufactured over a number of machines (i).

The production scheduling problem deals with obtaining the date for each job to enter on each machine Not necessarily physical machines, they may be stages (consisting on several machines or labour) in a manufacturing process Jobs have to be manufactured in each machine in a certain order (known as route) during a certain time period (known as processing time)Processing time of job in machine is usually denoted by pi,j. Both route and time period are given by the technological process.

Gantt chart

A representation of a specific solution of a scheduling problem in terms of the machines and job.

Computer aided design-CAD

Computer Aided Design-CAD is defined the use of information technology (IT) in the Design process. A CAD system consists of IT hardware (H/W), specialized software (S/W) (depending on the particular area of application) and peripherals, which in certain applications are quite specialized. The core of a CAD system is the S/W, which makes use of graphics for product representation; databases for storing the product model and drives the peripherals for product presentation. Its use does not change the nature of the design process but as the name states it aids the product designer. The designer is the main actor in the process, in all phases from problem identification to the implementation phase. The role of the CAD is in aiding him/her by providing:

1. Accurately generated and easily modifiable graphical representation of the product. The user can nearly view the actual product on screen, make any modifications to it, and present his/her ideas on screen without any prototype, especially during the early stages of the design process.
2. Perform complex design analysis in short time. Implementing Finite Elements Analysis methods the user can perform.
3. Static, Dynamic and Natural Frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis, Design optimization
4. Record and recall information with consistency and speed. In particular the use of Product Data Management (PDM) systems can store the whole design and processing history of a certain product, for future reuse and upgrade.

The first applications were for 2D-Drafting and the systems were also capable of performing only 2D modelling. Even today 2D-drafting is still the main area of application (in terms of number of workplaces). Later, (mid-1980), following the progress in 3D modelling technology and the growth in the IT H/W, 3D modelling systems are becoming very popular. 3D modelling are at the beginning wire frame based. Aerospace and automotive industries were using surface modelling systems for exact representation of the body of the product. At the same time solid modelling was recognized as the only system, which could provide an unambiguous representation of the product, but it was lacking adequate support for complex part representations. Today we are experiencing a merge of solid and surface modelling technology. Most solid modelling systems are capable of modelling most of industrial products. Systems sold today (especially for mechanical applications, which are the majority of systems sold world-wide) are characterized as NURBS (Non Uniform Rational B-Sline) based systems, employing solid modelling technology, and they are parametric and feature based systems. The use of CAD systems has also been expanded to all industrial sectors, such AEC,Electronics, Textiles, Packaging, Clothing, Leather and Shoe, etc. Today, numerous CAD systems are offered by several vendors, in various countries.

Objectives of the technique:

Originally the technique was aiming at automating a number of tasks a designer is performing and in particular the modelling of the product. Today CAD systems are covering most of the activities in the design cycle, they are recording all product data, and they are used as a platform for collaboration between remotely placed design teams. Most of its uses are for manufacturing and the usual name of the application is CAD/CAM. The areas of application of CAD related techniques, such as CAD, CAEngineering and CAManufacturing . Each of the above functions is not accomplished by a single system and it is quite often for a company to use more that one system, especially when we have CAD and CAE applications. CAD systems can shorten the design time of a product. Therefore the product can be introduced earlier in the market, providing many advantages to the company.

CAD Systems:

Current systems, especially for mechanical products are 3D systems and they are spreading now their dominance to the other sectors. 3D modelling can be Wire Frame, Surface or Solid Modelling. Most of the mid-range mechanical sector CAD systems are Parametric and Feature Based Solid Modelling systems. Wire frame modelling was the first attempt to represent the 3D object. The representation was inadequate with many drawbacks in terms of precision, adequacy of the representation, etc. In simple terms a 2D-wire frame model is built by forming the skeleton of the part, consisting only of edges.

Computer Aided Engineering Tools:

Engineering analysis is concerned with analysis and evaluation of engineering product designs. For this purpose, a number of computer-based techniques are used to calculate the product's operational, functional, and manufacturing parameters. Finite element analysis (FEA) is one of the most frequently used engineering analysis techniques. Besides FEA, tolerance analysis, design optimisation, mechanism analysis, and mass property analysis are some of the computer aided techniques available to engineers for the purposes of analysis and evaluation of the engineering product designs.

Finite-Element Analysis

Finite-element analysis is a powerful numerical analysis process widely used in engineering applications. FEA is used to analyse and study the functional performance of an object by dividing it into a number of small building blocks, called finite elements. For example, functional performances of an object or continuum, such as a structure's stresses and deflections, are predicted using FEA. The core of the FEA method is an idealization of the object or continuum by a finite number of discrete variables. For this purpose, the object is first divided into a grid of elements that forms a model of the real object. This process is also called meshing. Each element is a simple shape such as a square, triangle, or cube or other standard shape for which the Finite-element Program has information to write the governing equations in the form of a stiffness matrix. The unknown parameters for each element are the displacements at the node points, which are the points at which the elements are connected. The Finite-Element Program assembles the stiffness matrices for these simple elements to form the global stiffness matrix for the entire model. This stiffness matrix is solved for the unknown displacements, given the known forces and boundary conditions. From the displacement at the nodes, the stresses in each element can then be calculated. The following steps are usually followed in applying FEA:

1. Discretization of the given continuum
2. Selection of the solution approximation
3. Development of element matrices and equations
4. Assembly of the element equations
5. Solution for the unknown at the nodes
6. Interpretation of the result

A number of software packages for engineering analysis have been developed that are capable of covering a wide range of applications. These applications include: Static analysis, Transient dynamic analysis, Natural frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis.

Rapid Prototyping Tools and Machines:

Rapid prototype allows to "print" three-dimensional models of designs as easily as printing them on paper. It is a fast and cost-effective way to improve the way a designer communicates his/her ideas, both inside and outside the organization. It revolutionizes the development process, helping the design team to take advantage of more opportunities, more profitably than ever before. It's benefits help them win greater understanding -and faster approval- of their ideas, create superb models quickly and inexpensively, start building immediately -without training- and dramatically improve the way they do business.

Product Data Management Tools:

Product Data Management (PDM) is a tool that can be used to support the entire product life cycle including product or plant definition, production and business operations support. PDM technology provides a way for systems to work together and exchange information at multiple points of continuous integration, from design through manufacturing and support. In extended enterprises, PDM can be effective in managing the product definition supply chain by serving as an information bridge connecting OEMs, subcontractors, vendors, consultants, partners, and customers. PDM systems manage the full configuration of a product, including all mechanical, electronic, software, and documentation components. The technology is applicable to any discrete manufactured products such as automobiles, aircraft and defense systems, machine tools, and telecommunications equipment. Whether it relates to design concepts, prototypes, fabrication, operations, or maintenance, PDM assures that people and systems will have access to accurate information throughout the life cycle of a product.

Automated systems

• Production systems automated & computerized.

• Approaches & Technologies:

- Automation.
- Material Handling Technologies.
- Manufacturing Systems.
- Flexible Manufacturing.
- Computer integrated manufacturing (CAD, CAM).

Production Systems:

• Production system is a collection of People, Equipment, and Procedures to perform manufacturing.

• Production divided into two levels :

(a) Facilities: Factory, Equipment, and Layout.

(b) Manufacturing support systems: Set of procedures used to manage production.

Facilities:

• Manual Work Systems.

• Worker-Machine Systems.

• Automated Systems:

(a) System in which a process is performed by a machine without the direct participation of a human worker.

(b) Two Levels:

1.Semi Automated: perform a portion of work cycle

2.Fully Automated: operate for extended period without human attention.

Manufacturing Support Systems:

• To operate the production facilities efficiently:

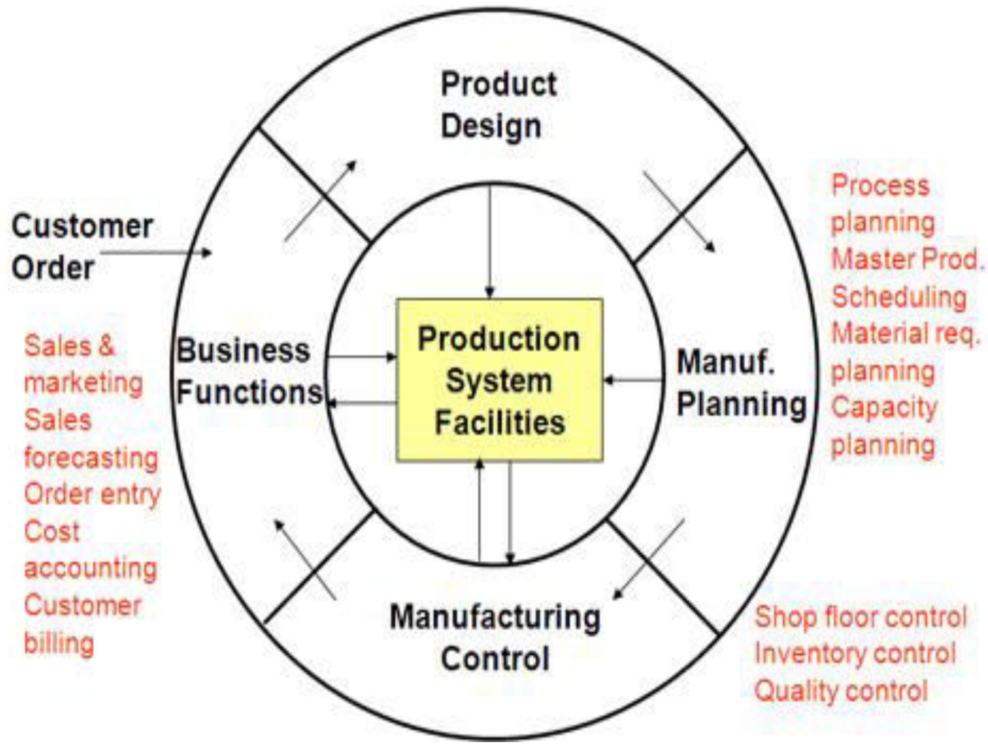
i. Design the processes and Equipments.

ii. Plan and control production orders.

iii. Satisfy product quality requirement.

• Support systems do not directly contact the product, but they plan and control its progress through the factory.

• Manufacturing support involves a cycle of information processing activities.



Automation in Production Systems:

• Two levels:

1. Automation in Manufacturing Systems.

2. Computerization of the Manufacturing Support Systems.

• In modern production system, two levels overlap.

• Computer Integrated Manufacturing (CIM) indicates use of computers at 2 levels.

Automated Manufacturing Systems:

• Operates in the factory on the physical product.

• Automated operations: Processing, Assembly, Inspection, Material Handling.

• Automated: Reduced level of Human intervention.

3 Basic Types of Automation:

1. Fixed Automation.

2. Programmable Automation.

3. Flexible Automation.

Fixed Automation:

• Sequence of processing operations is fixed by the equipment configuration.

• Sequence of simple operations.

• Integration and coordination of much operation in one equipment.

• Typical features:

1. High initial cost.

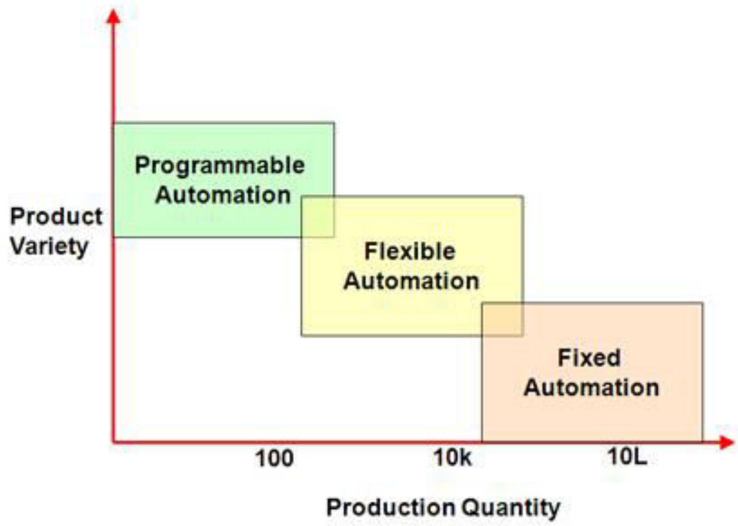
2. Custom engineered equipment.
3. High production rates.
4. Inflexibility.

Programmable Automation:

• Production equipment is designed with capability to change sequence of operation to accommodate different product configurations.
• Operation sequence controlled by PROGRAM.
• Typical features:
1. High investment in general purpose equipment.
2. Low production rate.
3. Flexibility to deal with product change.
4. High suitability for batch production.
• Typical cycle for a product:
1. Set up and reprogramming.
2. Batch production of parts.
• Examples:
1. NC Machine Tools.
2. Industrial Robots.
3. PLCs.

Flexible Automation:

Extension of programmable automation.
• Produce variety of parts with virtually no time lost for changeovers from one part style to next.
• No production time lost in set up and reconfiguration.
• System can produce various mixes of parts.
• Example: FMS.
• Typical Features:
1. High Investment for custom engineered equipments.
2. Continuous production of mix of products.
3. Medium production rates.
4. Flexible to deal with product design variations.



Automation Principles & Strategies:

• Automation is not always the right answer for a given production situation.

• Three approaches for dealing with automation projects:

1. The USA Principle.
2. Ten strategies for Automation.
3. Automation Migration Strategy.

The USA Principle:

• It is common Sense approach to automation and process improvement.

• USA Stands for:

U: understand the existing process.

S: simplify the process.

A: automate the process.

U: Understanding the Process:

a) First study current process in detail.

b) Find answers:

1. What are inputs?
2. What are outputs?
3. What exactly happens between input & output?
4. What is function of process?
5. How does it add value to the product?
6. What are sequences of operations?

S: Simplify the Process:

a) Simplify the existing process.

b) Generate answers to queries:

1. What is the purpose of each step and transport?

2. Is this step necessary?
3. Can this step be eliminated?
4. Does this step use the most appropriate technology?
5. How can the step be simplified?
6. Can steps be combined?
7. Automate the steps in process.

A: Automate the process:

Ten Strategies for Automation:-

- Specialization of operations: Special purpose equipment to perform one operation with greatest possible efficiency.
- Combined operations: Reducing number of distinct production machines.
- Simultaneous Operations: Reducing total processing time.
- Integration of operations: Linking several workstations into a single integrated mechanism.
- Increased flexibility: To achieve max utilization of equipment.
- Improved material handling and storage: Reducing non-productive time.
- On-line inspection: Corrections to the process during manufacturing.
- Process control and optimization.
- Plant operations and control.
- CIM.

Automation Migration Strategy:

- Phase 1: Manual Production using single station manned cells operating independently.
- Phase 2: Automated Production using single-station automated cells operating independently.
- Phase 3: Automated integrated production using a multistation automated system with automated material handling.