Welcome!

MECH 2060 Spring 2020
Manufacturing Process

Week 18.1

Prof. Junqiu Wang

Who Am I

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  - Open door policy
  - Email for appointment

About MECH2060

Textbook: Kalpakjian, S. and Schmid, S. R., Manufacturing Engineering and Technology, 7th Edition, Prentice, Hall, 2014.

Learning Objective

- Understand the fundamental manufacture process in industry, from the manufacturing of our everyday life product to large engineering tools
- Understand the properties of different materials and their impact on the manufacturing process
- Being able to use the knowledge of manufacture process and materials selection to evaluate and analyze a current/future

Learning Objectives

- Identify: product design & concurrent engineering processes, product life cycle, role of computers in product design, prototypes and rapid prototypes, green design & manufacturing, design for recycling, selection of materials, selection of manufacturing processes, quality assurance and total quality management, human-factors engineering and product liability.
- Develop fundamental knowledge of engineering materials structure and behavior: metal alloys, ferrous and non-ferrous metals, polymers, ceramics & glasses, and composite materials.
- Acquire practice of mechanical behavior, testing, and manufacturing properties of materials.
- Obtain basic understanding of different thermal heat treatments.
- Understand the fundamentals and methods of different Casting, Metal Forming and Rapid Prototyping/Manufacturing Processes.
- Understand the basic principles and physics of different processes so as to analyze the forces, power and energy requirements.
- Compare the pros and cons of different processes from the point of view of Manufacturability and economic considerations.
- Understand the impact of part design on the manufacturing of the part and develop basic suggestion for improving the manufacturability of the part.
- Understand the fundamental process of micro and nanofabrication for

Evaluation

Grading Structure

Quizzes	20%
First Exam (at the end of week 5)	30%
Second Exam (at the end of week-12)	30%
Final Project	20%

	A	**A-**	
	100-93	92-90	
B+	**B**	**B-**	
89-87	86-83	82-80	
C+	**C**	**C-**	
79-77	76-73	72-70	
D+	**D**	**D-**	**F**
69-67	66-63	62-60	59-0

Basics and Definitions

- What is Manufacturing
  - Manufacturing is concerned with making products.
  - A manufactured product may, in turn, itself be used to make other products.
- Examples:
  - A large press, to shape flat sheet metal into automobile bodies.
  - A drill, for producing holes.
  - Industrial sewing machines, for making clothing at high rates.
  - Machinery, to produce an endless variety of individual items, ranging from thin wire for guitars and electric motors to crankshafts and connecting rods for automotive engines.
  - Lithography, to make computer chips

Basics and Definitions

- Manufactured items begin with raw materials, which are then subject to a sequence of processes to make individual products.

In Summary:

- Objects that are built and assembled by combination of processes called “Manufacturing”

- Table-1 shows the approximate number of parts in a product.

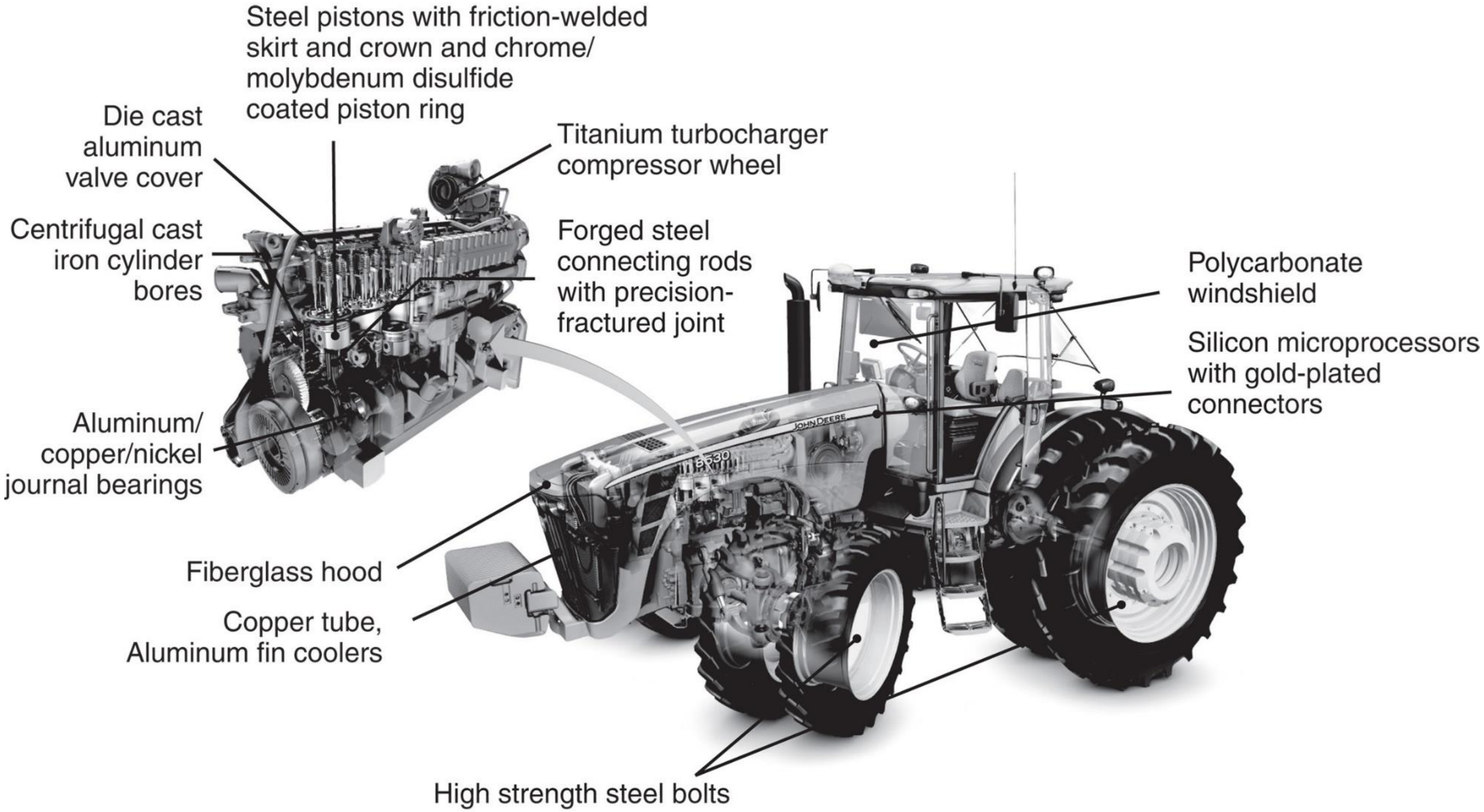
- Figure-1 shows A John Deere tractor which contains hundreds of parts and made of different materials.

TABLE I.1 Approximate Number of Parts in Products

TABLE I.1

Approximate Number of Parts in Products	
Common pencil	4
Rotary lawn mower	300
Grand piano	12,000
Automobile	15,000
Boeing 747–400	6,000,000

FIGURE I.1 Model 8430 John Deere tractor, with detailed illustration of its diesel engine, showing the variety of materials and processes incorporated. *Source:* Courtesy of John Deere Company.



Design Processes

There are two main processes:

1- The Traditional Design Process (lengthy one)

2- Concurrent Engineering Process (short one)Objects

Traditional Design Process

In General

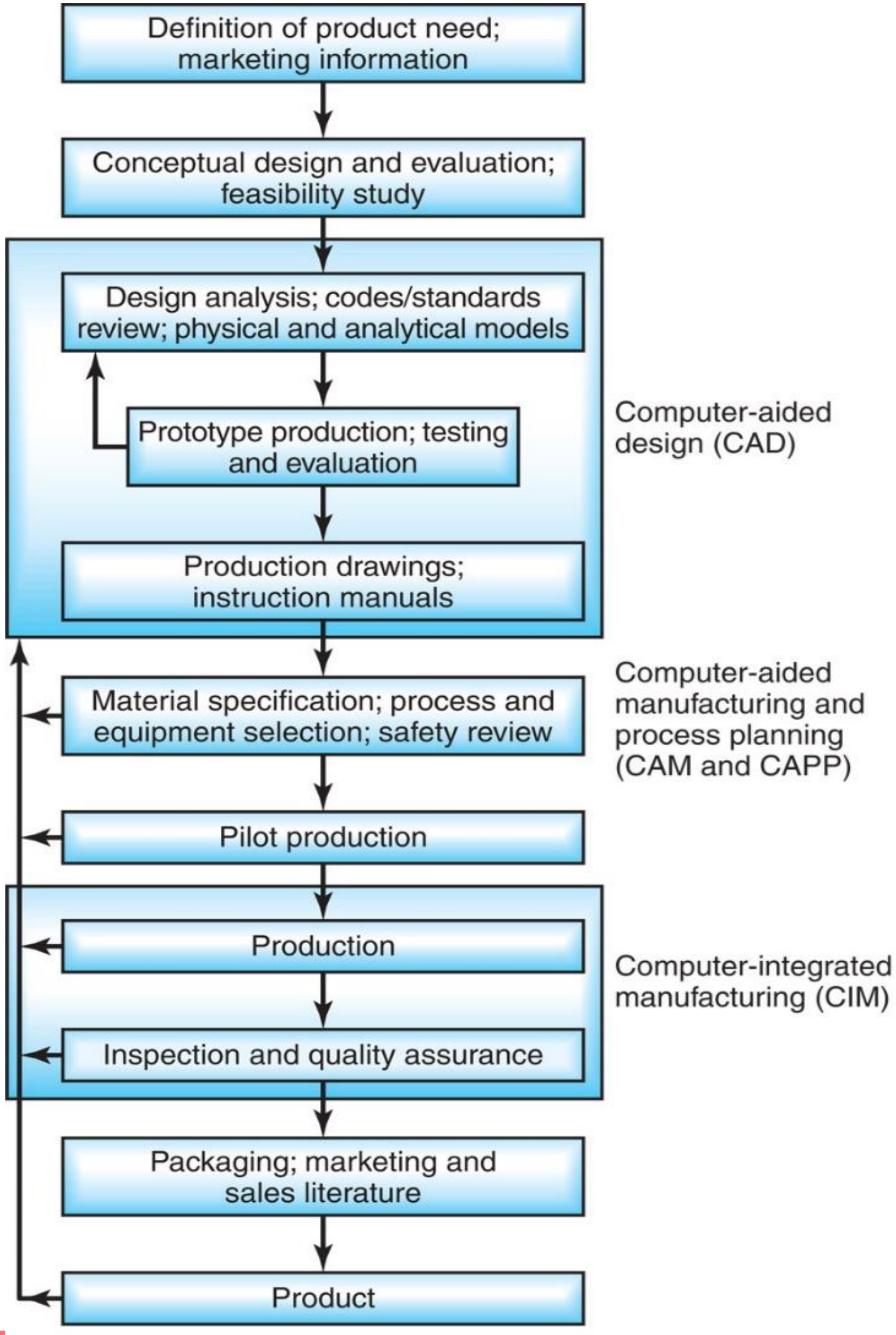
- Design and manufacturing activities are happening successively
- Sequentially

Design

- Problem definition, understand the market
- Conceptual design, evaluation on constraints, feasibility(CAD)
- Prototyping, testing (3-D printer)
- Final design

Manufacturing

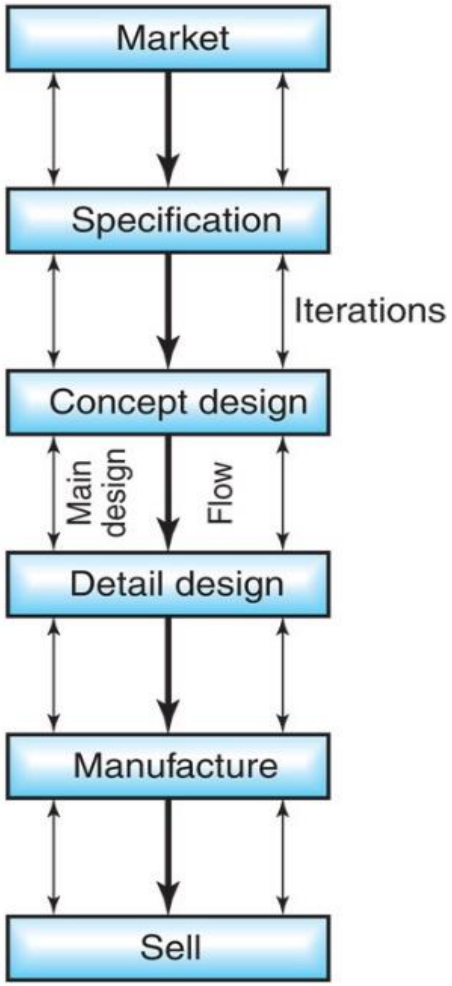
- Material selection, process and equipment(materials engineering, industrial engineering)
- Pilot product
- Final production
- Inspection and quality assurance (Statistics)



(a)

Concurrent design process

- Driven primarily by the consumer electronics industry (laptops, cell phones, video game console etc.)
- Materials selections, process being integrated into conceptual design
- bring products to the marketplace as rapidly as possible, so as to gain a higher percentage share of the market and thus higher profits
- simultaneous engineering



(b)

Life Cycle of a Product

A product has four stages for its life cycle:

1- Product start up
2- Rapid Growth in the market
3- Product maturity
4- Decline/Disposal

In Summary

Life-cycle engineering requires that the entire life of a product be considered, beginning with the design stage and on through production, distribution, product use, and, finally, recycling(Cradle to Cradle) or disposal(Cradle to Grave)of the product.

Role of Computers in Product Design

- Computer aided design (CAD)
  - Modeling of the preliminary design
  - Analysis of the design: structure, loads etc.

- Computer-aided manufacturing (CAM)
  - CAM involves all phases of manufacturing by utilizing and processing the large amount of information on materials and processes gathered and stored in the organization's database.
  - Programming for numerical-control machines, robots for materials handling
  - Designing tools
  - Maintaining quality control

https://www.youtube.com/watch?v=2RBOtd-Z8O8

Prototypes and Rapid Prototypes

- A prototype is a physical model of an individual component or product.
- The prototypes are carefully reviewed for possible modifications to the original design, materials, or production methods.
- Rapid prototyping
  - Using CAD/CAM and various specialized technologies, designers can now make **prototypes rapidly and at low cost**, from metallic or nonmetallic materials such as plastics and ceramics.
  - 3-d Printer
  - CNC machining

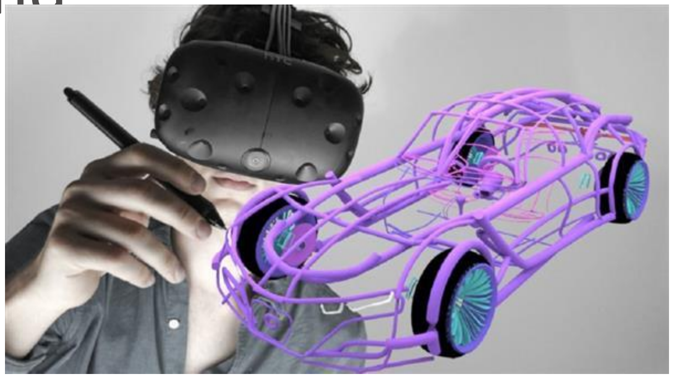
https://www.youtube.com/watch?v=OhNnKTaciVI

Example of Prototyping

Virtual prototyping

- Virtual prototyping is a software-based method that uses advanced graphics and **virtual-reality** environments to allow designers to view and examine a part in detail.
- This technology, also known as simulation-based design, uses CAD packages to render a part such that, in a 3-D interactive virtual environment, designers can observe and evaluate the part as it is being developed.
- Virtual prototyping has been gaining importance, especially because of the availability of low-cost computers and simulation and analysis tools.

https://www.youtube.com/watch?v=F-zeuqEtv9o



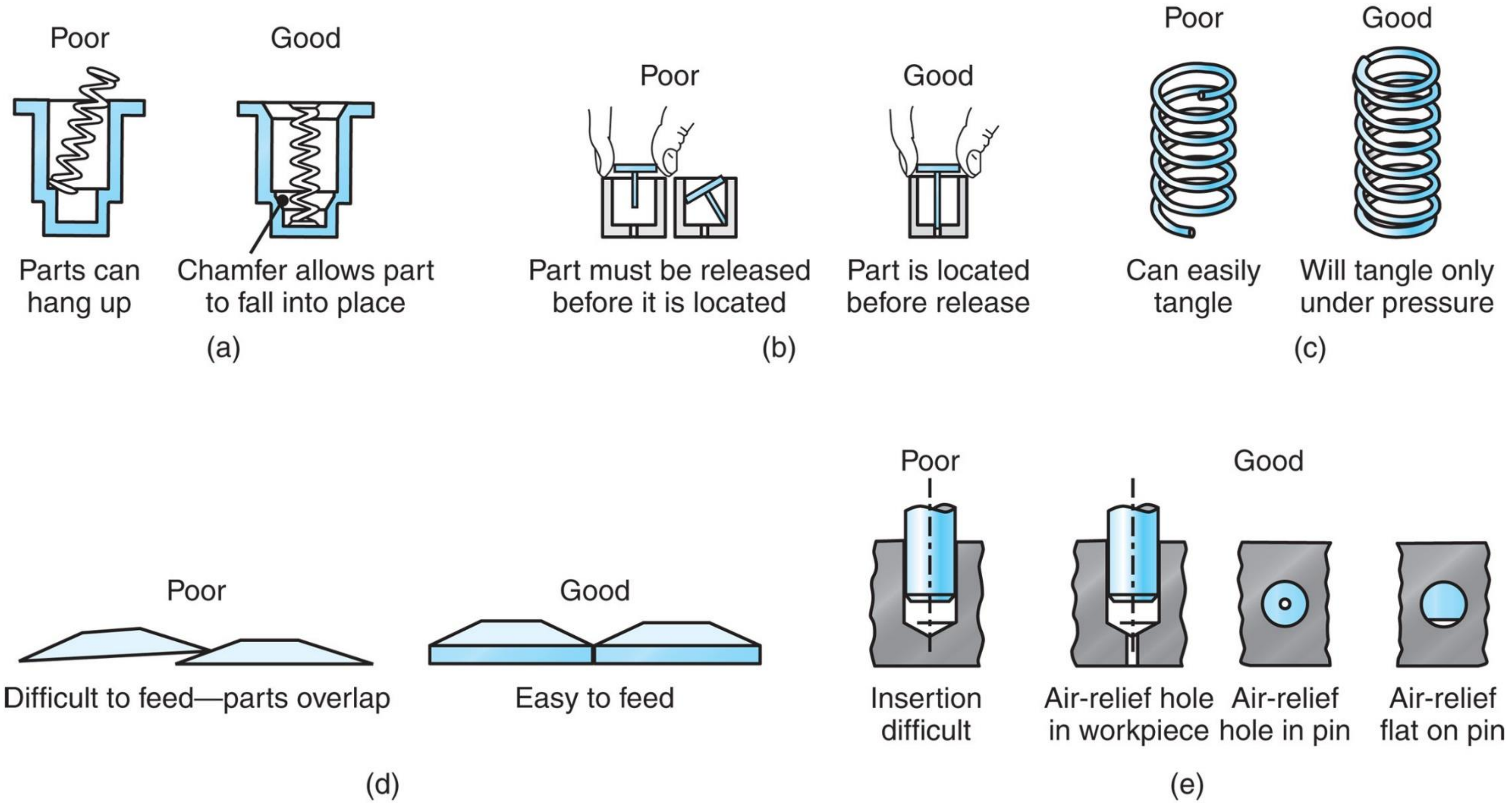
Design for Manufacture, Assembly, Disassembly, and Service

- Design For Manufacture (DFM) is a comprehensive approach to integrating the design process with production methods, materials, process planning, assembly, testing, and quality assurance.
- Design For Assembly (DFA): Assembly is an important phase of manufacturing, requiring considerations of the ease, speed, and cost of putting together the numerous individual components of a product. Design For Manufacture and Assembly (DFMA).
- Design For Disassembly (DFD): Disassembly of a product is an equally important consideration, for such activities as maintenance, servicing, and recycling of individual components.

Design for Manufacture, Assembly, Disassembly, and Service

- Design for Service (DFS):Design for service is an important aspect of product design. Products often have to be dis-assembled to varying degrees in order to service them and, if necessary, repair them.
- The design should take into account the concept that, for ease of access, components that are most likely to be in need of servicing be placed, as much as possible, at the outer layers of the product. This methodology can be appreciated by anyone who has had the experience of servicing machinery.
- Figure 1-3 shows the redesign of parts to facilitate assembly

FIGURE I.3 Redesign of parts to facilitate assembly. *Source:* After G. Boothroyd and P. Dewhurst.



Green Design and Manufacturing

- Particular manufacturing process and the operation of machinery can each have a significant environmental impact. Manufacturing operations generally produce some waste, such as:
  - Chips from machining and trimmed materials
  - Slag from foundries and welding operations
  - Additives in sand used in sand-casting operations
  - Hazardous waste and toxic materials.
  - Lubricants and coolants.
  - Liquids from processes such as heat treating.
  - Solvents from cleaning operations
  - Smoke and pollutants from furnaces and gases from burning fossil fuels

Green Design and Manufacturing

- The adverse effects of these activities, their damage to our environment and to the Earth's ecosystem, and, ultimately, their effect on the quality of human life are now widely recognized and appreciated.
- Major concerns involve global warming, green house gases (carbon dioxide, methane, and nitrous oxide), acid rain, ozone depletion, hazardous wastes, water and air pollution , and contaminant seepage into water sources.
- Design For the Environment (DFE): this approach considers all possible adverse environmental impacts of materials, processes, operations, and products, so that they can all be taken into account at the earliest stages of design and production.

Design for Recycling

- To achieve the goals of (DFE), a new concept has been considered, Design For Recycling (DFR).
- Recycling may involve one of two basic activities: biological and industrial
- Biological cycle: Organic materials degrade naturally, and in the simplest version of a biological cycle, they lead to new soil that can sustain life; thus, product design involves the use of (usually) organic materials. The products function well for their intended life and can then be safely discarded.
- Industrial cycle: The materials in the product are recycled and reused continuously.

Design for Recycling

Example of Aluminum Beverage Recycling

- Aluminum Beverage Cans are recycled and the metal is reused.
- To demonstrate the economic benefits of this approach, it has been estimated that producing aluminum from scrap, instead of from bauxite ore, reduces production costs by as much as 66% and reduces energy consumption and pollution by more than 90%.

Guidelines for Green Design and Manufacturing

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- There are relationships among the basic concepts of DFMA, DFD, DFE, and DFR. These relationships can be summarized as guidelines:
- Reduce waste of materials.
- Reduce the use of **hazardous materials** in products and processes.
- Investigate manufacturing technologies that produce environmentally friendly and safe products and by-products.
- Make improvements in methods of recycling, waste treatment, and reuse of materials.
- Minimize energy use and, whenever possible, encourage the use of renewable sources.
- Encourage recycling.

Selection of Materials

- The selection of materials for products and their components is made in consultation with materials engineers. The common used materials are:
  - Ferrous metals: Carbon alloy, stainless, and tool and die steels.
  - Nonferrous metals: Aluminum, magnesium, copper, nickel, titanium, ..etc.
  - Plastics (polymers).
  - Ceramics, glasses, graphite, and diamond.
  - Composite materials: Reinforced plastics and metal-matrix and ceramic-matrix composites.
  - Nanomaterials.
  - Shape-memory alloys (smart materials), semiconductors, and superconductors.

TABLE I.3 General Manufacturing Characteristics of Various Materials

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TABLE I.3

General Manufacturing Characteristics of Various Materials

Alloy	Castability	Weldability	Machinability
Aluminum	Excellent	Fair	Excellent–good
Copper	Good–fair	Fair	Good–fair
Gray cast iron	Excellent	Difficult	Good
White cast iron	Good	Very poor	Very poor
Nickel	Fair	Fair	Fair
Steels	Fair	Excellent	Fair
Zinc	Excellent	Difficult	Excellent

The ratings shown depend greatly on the particular material, its alloys, and its processing history.

Selection of Manufacturing Processes

- Casting (Fig. I.5a): Expendable mold and permanent mold
- Forming and shaping (Figs. I.5b–d): Rolling, forging, extrusion, drawing, sheet forming, powder metallurgy, and molding (Part III)
- Machining (Fig. I.5e): Turning, boring, drilling, milling, planing, shaping,broaching; grinding; ultrasonic machining; chemical, electrical, and electrochemical machining; and high-energy-beam machining (Part IV); this broad category also includes micromachining for producing ultraprecision parts (Part V)
- Joining (Fig. I.5f): Welding, brazing, soldering, diffusion bonding, adhesivebonding, and mechanical joining (Part VI)
- Finishing: Honing, lapping, polishing, burnishing, deburring, surface treating, coating, and plating (Chapters 26 and 34)
- Microfabrication and nanofabrication: Technologies that are capable of producing parts with dimensions at the micro (one-millionth of a meter) and nano (one-billionth of a meter) levels; fabrication of microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS), typically involving processes such as lithography, surface and bulk micromachining, etching, LIGA, and various other specialized processes (Chapters 28 and 29)

FIGURE I.5a Schematic illustrations of various casting processes.

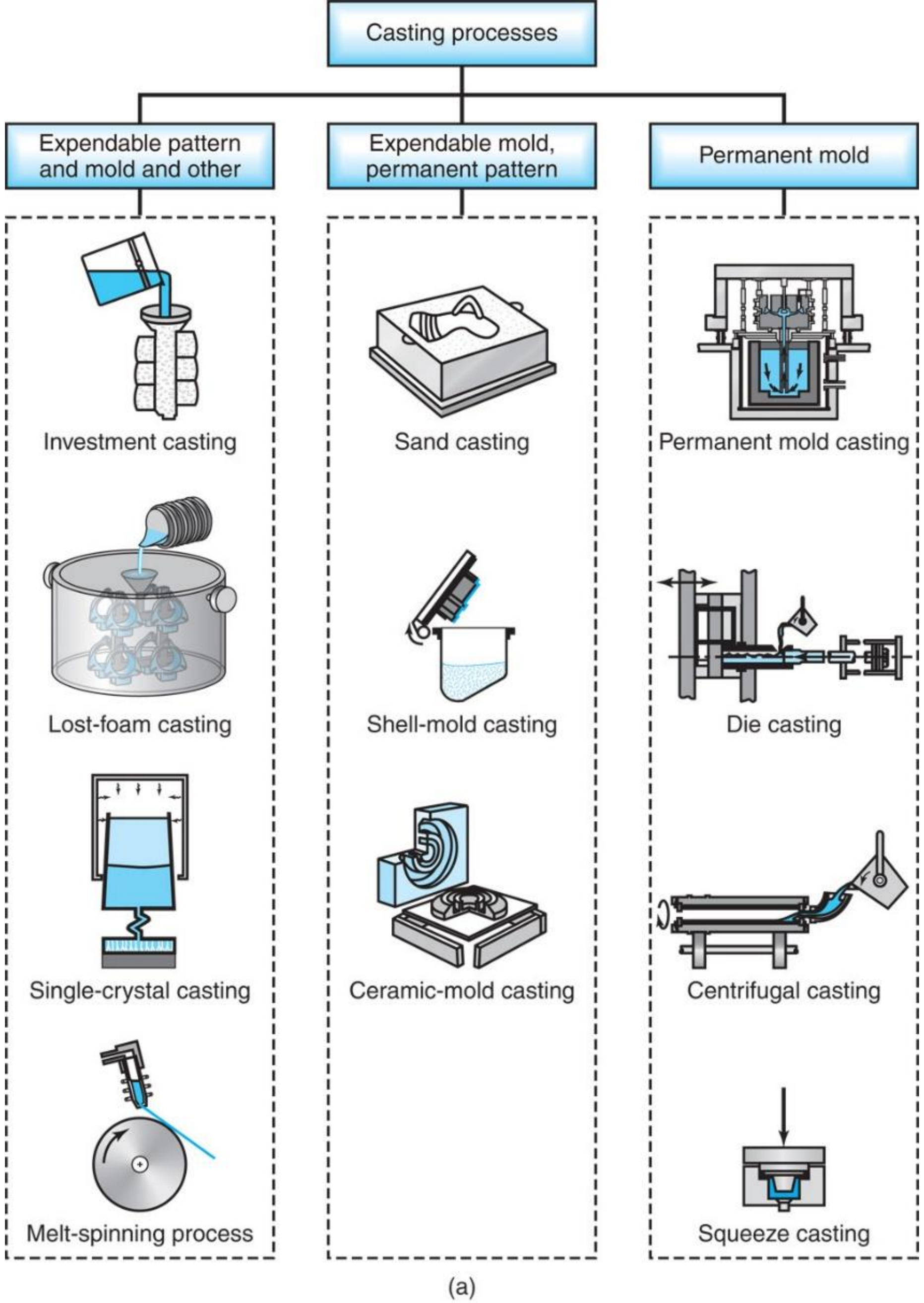


FIGURE I.5b Schematic illustrations of various bulk-deformation processes.

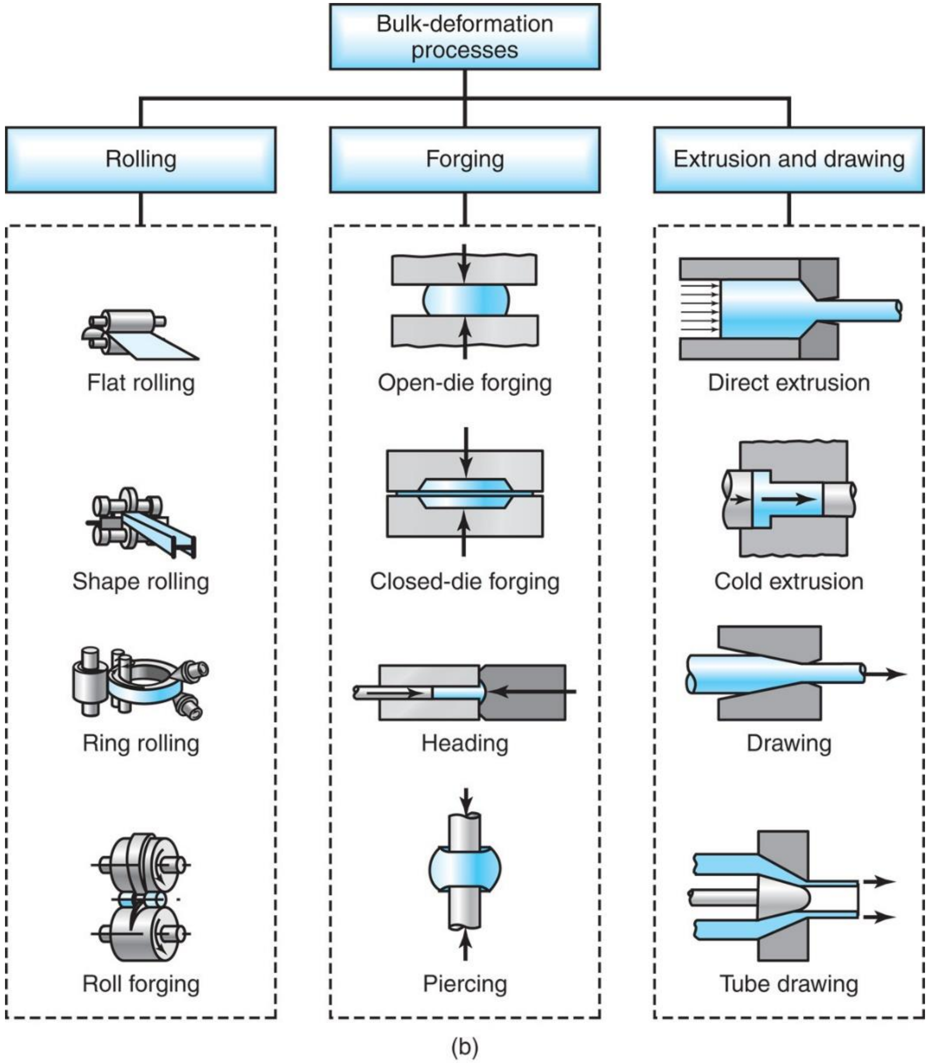


FIGURE I.5c Schematic illustrations of various sheet-metal forming processes.

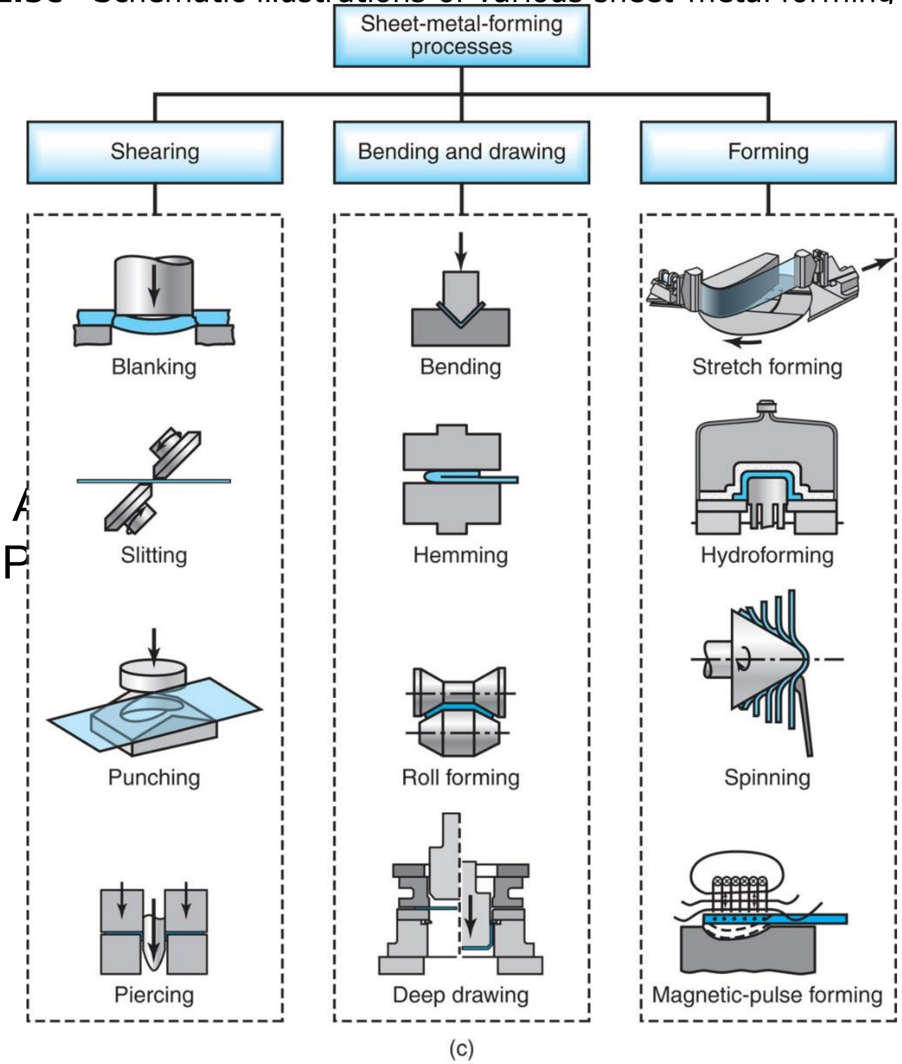


FIGURE I.5d Schematic illustrations of various polymer-processing methods.

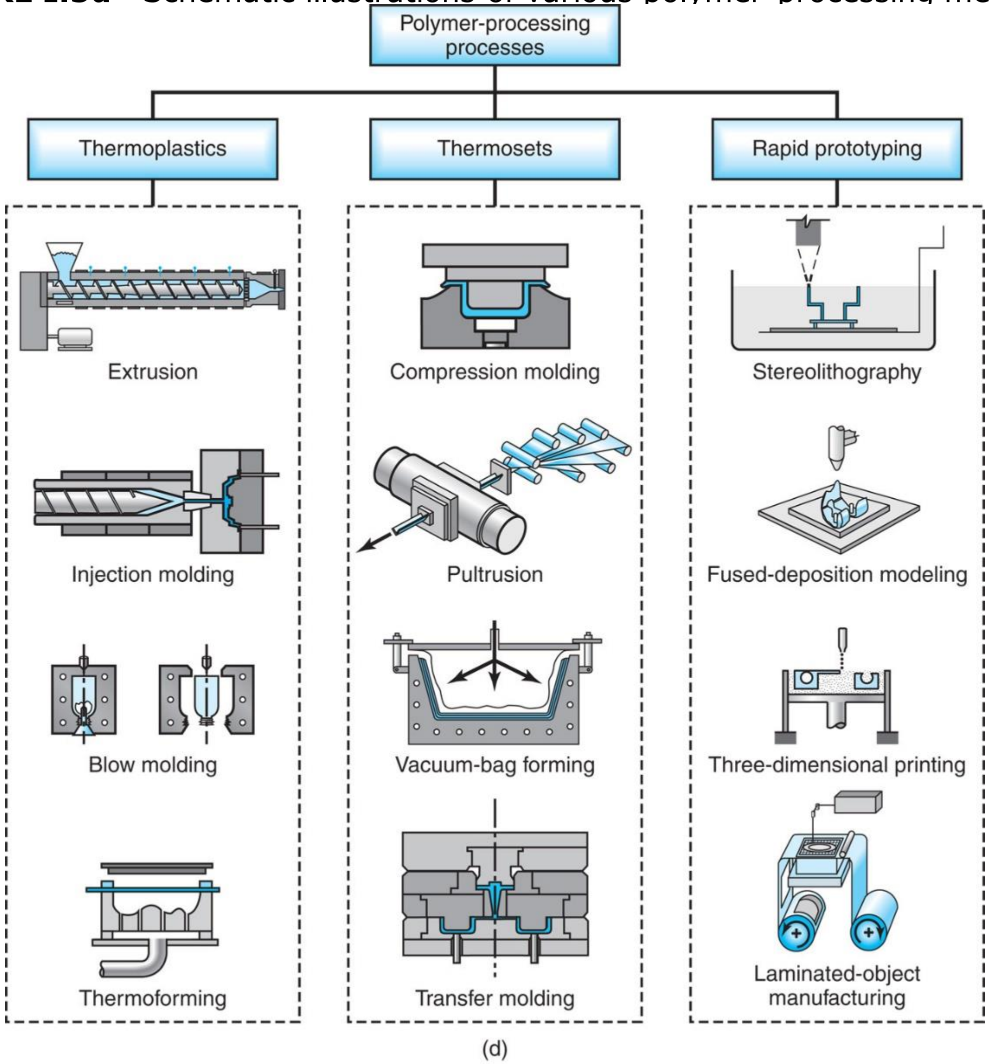
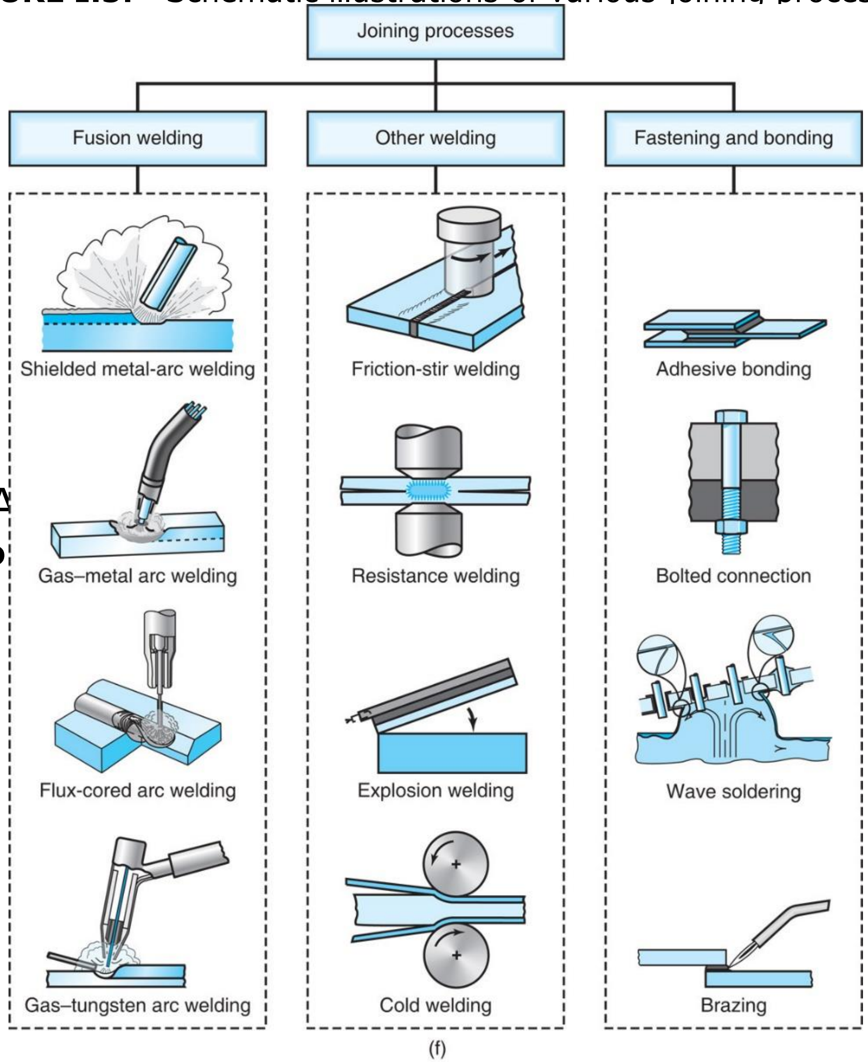


FIGURE I.5f Schematic illustrations of various joining processes.



A

P

Process Selection

Process selection depends on:

- Geometric features of the part.
- Required properties: ductile/brittle
- Shape complexity
- Dimension accuracy
- Surface finish

Types of Production

- Job Shops production: small lot size < 10 parts. General purpose milling and drilling machines are used.
- Small-Batch production: from 10 to 100 using same machines as in job shops.
- Batch Production: 100 to 5000 using more advanced machines with computer controls.
- Mass production: > 100000 using special purpose automated machines.

Computer-integrated Manufacturing

Computer-Integrated Manufacturing (CIM): integrates the software and hardware needed for computer graphics, computer-aided modeling, and computer-aided design and manufacturing activities, from initial product concept through its production and distribution in the marketplace.

- Responsiveness to rapid changes in product design modifications and to varying market demands
- Better use of materials, machinery, and personnel
- Reduction in inventory

Better control of production and management of the total manufacturing operation

Quality Assurance and Total Quality Management

- Product quality must be from initial design to all different stages.
- Quality assurance and total quality management (TQM) are widely recognized as being the responsibility of everyone involved in the design and manufacture of products and their components.
- Product integrity is a term generally used to define the degree to which a product
  - Functions reliably during its life expectancy
  - Is suitable for its intended purpose
  - Can be maintained with relative ease

Quality Standards

- Global manufacturing and competitiveness have led to a need for international conformity and consensus in establishing quality control methods.
- This need resulted in the establishment of the ISO 9000 standards series on quality management and quality assurance standards, as well as of the QS 9000 standards introduced in 1994 .
- A company's registration for these standards, which is a quality process certification and not a product certification, means that the company conforms to consistent practices as specified by its own quality system.

Human-factors Engineering

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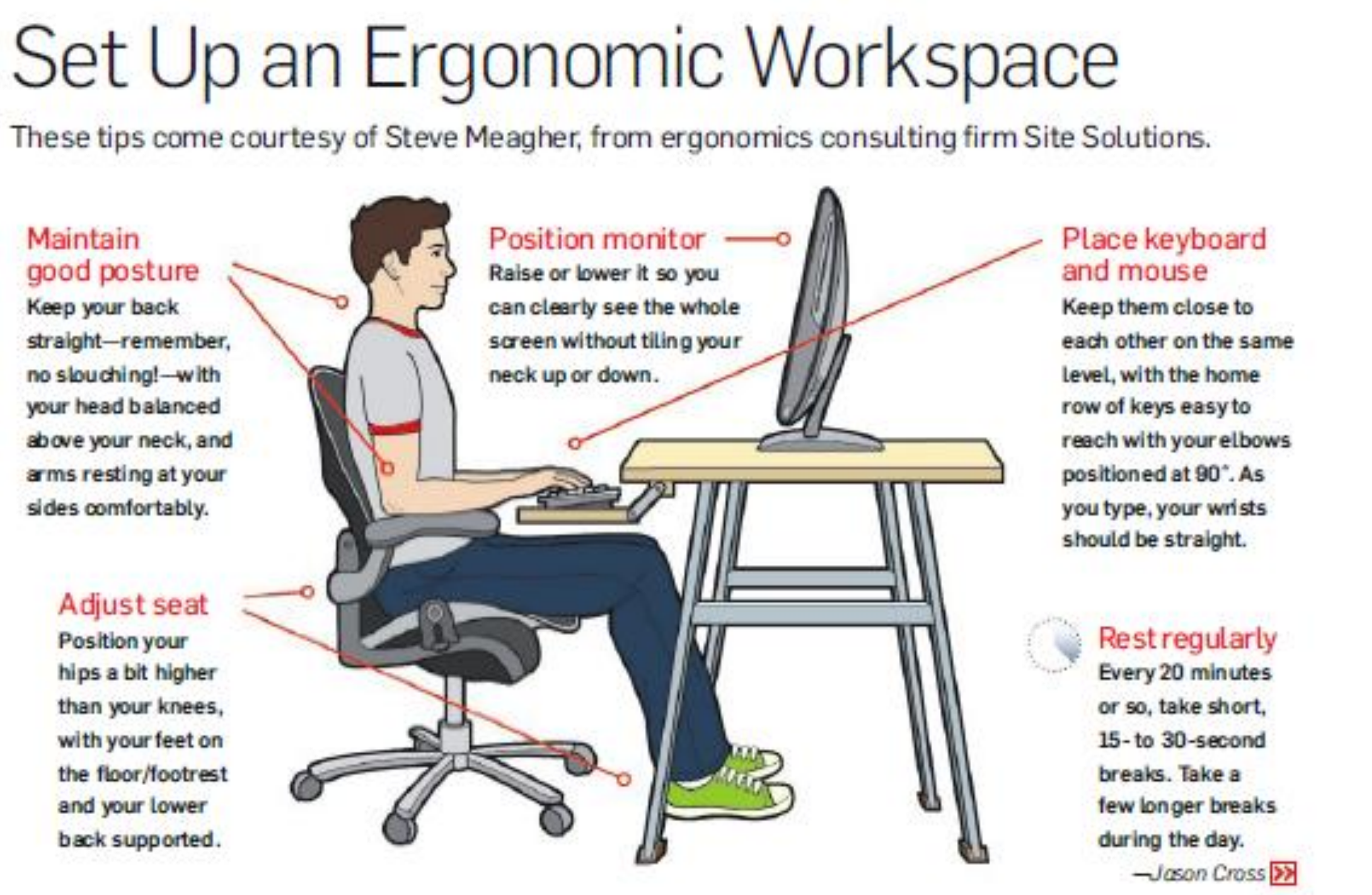
- This topic deals with human-machine interactions, to reduce potential human errors

Human-factors Engineering

- The human-factors approach: ergonomics, defined as the study of how a workplace and the machinery and equipment in it can best be designed and arranged for comfort, safety, efficiency, and productivity.



Product Liability

- Designing and manufacturing safe products is an essential aspect of a manufacturer's responsibilities.
- All those involved with product design, manufacture, and marketing must fully recognize the consequences of a product's failure, including failure due to predictable mistreatment of the product.
- A product 's failure can cause bodily injury or even death, as well as financial loss to an individual, a bystander, or an organization.
- This important topic is referred to as product liability.
- The laws governing it generally vary from state to state and from country to country

Lean Production and Agile Manufacturing

- Lean Production (Manufacturing) is a methodology that involves a thorough assessment (evaluation) of each activity of a company, with the basic purpose of minimizing waste at all levels and calling for the elimination of unnecessary operations that do not provide any added value to the product being made.

- The principle behind Agile (responsive) Manufacturing is ensuring agility, hence flexibility , in the manufacturing enterprise, so that it can respond rapidly and effectively to changes in product demand and the needs of the customer.

Manufacturing cost and Global competition

- Total cost of manufacturing of a product consists of
  - Materials
  - Tooling
  - Fixed: rent for facility, real-estate taxes, insurance
  - Capital: production machinery, equipment, buildings, and land are typical capital costs
  - Labor: Labor costs consist of direct and indirect costs. Direct labor, also called productive labor, concerns the labor that is directly involved in manufacturing products. Indirect labor, also called nonproductive labor or overhead, pertains to servicing of the total manufacturing operation.

TABLE I.6 Typical Cost Breakdown in Manufacturing

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TABLE I.6

Typical Cost Breakdown in Manufacturing	
Design	5%
Materials	50%
Manufacturing	
Direct labor	15%
Indirect labor	30%

TABLE I.7 Approximate Relative Hourly Compensation for Workers in Manufacturing in 2010 (United States = 100)

TABLE I.7

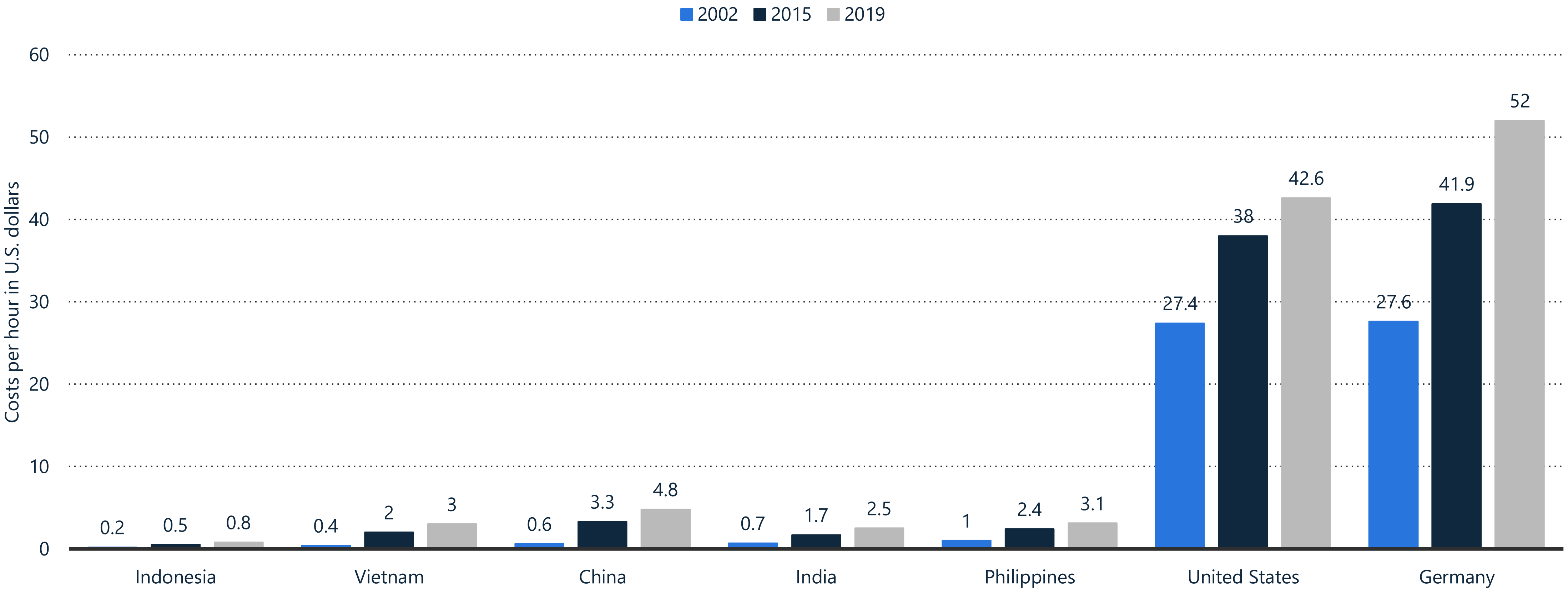
Approximate Relative Hourly Compensation for Workers in Manufacturing in 2010 (United States = 100)

Norway	166	Italy	96
Switzerland	153	Japan	92
Belgium	146	Spain	76
Denmark	131	New Zealand	59
Germany	126	Israel	58
Sweden	126	Singapore	55
Finland	122	Korea (South)	48
Austria	118	Argentina, Slovakia	36
Netherlands, Australia	118	Portugal	34
France	117	Czech Republic	33
Ireland	104	Poland	23
United States	100	Mexico	18
Canada	97	China, India, Philippines	6

Note: Compensation can vary significantly with benefits. Data for China and India are estimates, they use different statistical measures of compensation, and are provided here for comparison purposes only.
Source: U.S. Department of Labor.

Manufacturing labor costs per hour for select countries from 2002 to 2019 (in U.S. dollars)

Manufacturing labor costs per hour for select countries 2002-2019



Note: Worldwide; 2014

Further information regarding this statistic can be found on page 8.

Source(s): A.T. Kearney; Economist Intelligence Unit; ID 744060

Reading Assignment

Reading Assignments

1. Introduction

a. Historical development of materials, tools, and manufacturing processes, Page-3.
b. Carbon footprint, and cradle-to-cradle production, Page-12.
c. Availability and reliability of supply of materials, Page-14.
d. Service life of a product, Page-14.
e. Case-Study 1.3 Saltshaker and Pepper Mill, Page-24
f. The various elements in Computer-Integrated Manufacturing (CIM), Pages-25:27.
g. Manufacturing Costs and Global Competition, and Trends in Manufacturing, Pages-31:32