12. Design and Manufacturing Engineering

Design and Manufacturing Engineering focuses on tools and techniques to conceptualize, engineer, produce, and qualify physical products across feature-scales, production quantities, and application domains. From an industrial engineering viewpoint, this knowledge area is concerned with the development, optimization, and standardization of methods to transform raw materials into functional products to satisfy the applications' and stakeholders' requirements in the most time and cost-efficient manner.

12.1. Engineering Design

- 12.1.1. Product design methodology (see Product Design and Development knowledge area)
- 12.1.2. Dimensions, tolerances, limits, and fits
- 12.1.3. Computer aided design (CAD)
- 12.1.4. Physical modeling and prototyping
- 12.1.5. Design for X methodologies (design for machining, design for additive manufacturing, design for assembly, design for quality, etc.)
- 12.1.6. Other important considerations in product, process, and systems design – sustainability, legal, and ethical issues

12.2. Fundamentals of Materials

- 12.2.1. Types of engineering materials: metals, polymers, ceramics, and composites
- 12.2.2. Atomic and crystalline structure
- 12.2.3. Mechanical properties of materials
- 12.2.4. Physical properties of materials: thermal, electrical, and biological

12.3. Solidification-based Manufacturing Processes

- 12.3.1. Metal solidification, fluid flow, and heat transfer
- 12.3.2. Metal casting: expendable and permanent mold processes
- 12.3.3. Design for metal casting
- 12.3.4. Casting quality and inspection methods
- 12.3.5. Polymer processing: thermoplastics, thermosets, and polymer-matrix composites processing
- 12.3.6. Design for polymer processing
- 12.3.7. Quality considerations for processed polymer parts

12.4. Material Removal Processes

- 12.4.1. Theory of metal cutting
- 12.4.2. Conventional machining processes: turning, milling, drilling, and related operations and tools
- 12.4.3. Abrasive machining processes
- 12.4.4. Non-traditional machining processes
- 12.4.5. Machinability and quality considerations
- 12.4.6. Design for machining

12.5. Forming-based Processes
- 12.5.1. Fundamentals of metal forming
- 12.5.2. Bulk deformation processes: rolling, forging, extrusion, and related operations
- 12.5.3. Sheet metal working processes
- 12.5.4. Design for metal forming
- 12.5.5. Quality considerations

12.6. Particulate Processing
- 12.6.1. Characterization of engineering powders
- 12.6.2. Powder metallurgy
- 12.6.3. Ceramics processing
- 12.6.4. Design and quality considerations

12.7. Joining Processes
- 12.7.1. Welding: fusion and solid-state processes
- 12.7.2. Brazing, soldering, adhesive bonding, and related operations
- 12.7.3. Design and quality considerations

12.8. Additive Manufacturing (AM)
- 12.8.1. Fundamentals of AM
- 12.8.2. Categories and principles or AM processes
- 12.8.3. Design and material considerations in AM
- 12.8.4. Economics of AM
- 12.8.5. Hybrid AM: integration with traditional manufacturing processes

12.9. Biomedical Manufacturing (BM)
- 12.9.1. Fundamentals and categories of BM
- 12.9.2. Design and material considerations in BM
- 12.9.3. Principles of BM processes for polymer devices
- 12.9.4. Principles of BM processes for metal implants
- 12.9.5. Principles of BM processes for polymer scaffolds
- 12.9.6. Principles of BM processes for bioink constructs
- 12.9.7. Regulatory and economic considerations in BM

12.10. Micro and Nano-scale Manufacturing
- 12.10.1. Fundamentals of scaling
- 12.10.2. Deposition processes
- 12.10.3. Etching processes
- 12.10.4. Doping and surface modification
- 12.10.5. Lithography processes
- 12.10.6. Surface and wet bulk micromachining
- 12.10.7. LIGA
- 12.10.8. Scanning probe-based processes
- 12.10.9. Self-assembly processes

12.10.10. Economic considerations

12.11. Manufacturing Planning
- 12.11.1. Process planning
- 12.11.2. Group technology and product families
- 12.11.3. Computer aided manufacturing (CAM)
- 12.11.4. Concurrent engineering
- 12.11.5. Metrology: measurement and inspection
- 12.11.6. Quality control and assurance
- 12.11.7. Lean manufacturing and Six Sigma
- 12.11.8. Cost estimation and economics of manufacturing

12.12. Manufacturing Systems
- 12.12.1. Automation and systems integration
- 12.12.2. Numerical control
- 12.12.3. Robotics
- 12.12.4. Production and assembly lines
- 12.12.5. Production systems, planning, and control
- 12.12.6. Flexible manufacturing systems
- 12.12.7. Computer integrated manufacturing (CIM)
- 12.12.8. Cellular manufacturing
- 12.12.9. Industry 4.0: digital and smart manufacturing

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