ME Core Curriculum

- The core subjects such as Mechanics (including Statics), Dynamics, Heat Transfer, Thermodynamics, Fluid Mechanics, etc.
- They are the laws of nature which allow you to solve problems (resolving a set of inputs to a set of desired output)
- This course uses the knowledge gain in the core subjects to achieve success designs

What is Design?

- Design is to formulate a plan for the satisfaction of a specified need or to solve a problem.
- An innovative and highly iterative, decision-making process, sometime without enough information.
- If the plan results into a product, it must be functional, safe, reliable, competitive, usable, manufacturable and marketable.
- A communication-intensive activity in word and mathematics and picture and graphics

Mechanical Engineering Design

- Involves all the disciplines of mechanical engineering
- This course focuses on machine component design.
- Rational Decision making
  - Suitability, Feasibility, Acceptability
  - Satisfactory Alternative
  - Specification Set – drawings, text, bills of materials
  - Decision Set – Size, Tolerance, Material, etc.
  - Prior design vs Design Variable
  - The adequate assessment
  - Figure of Merit
  - A Skill of Synthesis

Introduction

The invention all admir’d, and each, how he
to be th’ inventor missed; so easy it seem’d
Once found, which yet unfound most would
have thought Impossible

John Milton
Phases and Interactions of Design Process

- Identification of need – Recognizing and Phasing of the need
- Definition of problem – Define the specifications for the object to be designed. The specifications include the cost, the number to be manufactured, the expected life, the range, the operating temperature, and the reliability.
- Synthesis – the invention of concept or concept design – Proposed, investigated and quantified with established metrics
- Analysis & Optimization – Iterative process
- Evaluation
- Presentation – ‘a selling job’

Design Failure

- Union Carbide plant in Bhopal, India
- Nuclear power plant in Chernobyl, Soviet
- Collapse of Sampoong Department Store in Seoul, Korea on June 29, 1993 - 502 people were killed and 937 injured.
- NASA Space Shuttle – Foam damaging the Tile.
- Design
- The Hyatt Regency hotel walkway collapse was a major disaster that occurred on July 17, 1981 in Kansas City, Missouri.
- Three Mile Island Power Plant Accident on March 28, 1979
- http://www.hazardcards.com/card.php?id=1

Bhopal Disaster of 1984

- the worst industrial disaster in history
- the accidental release of 40 tons of methyl isocyanate (MIC) from a Union Carbide India, Limited (now Eveready Industries India, Limited) pesticide plant in the city of Bhopal, Indian.
- injured 150,000 to 600,000 people, at least 15,000 of whom later died

Chernobyl disaster (1986)

- Large areas of Ukraine, Belarus, and Russia were badly contaminated, resulting in the evacuation and resettlement of over 336,000 people.
- The disaster released as much as 300 times more radioactive fallout than the atomic bomb of Hiroshima.
- Greenpeace estimates a total death toll of 93,000 but cites in their report “The most recently published figures indicate that in Belarus, Russia and the Ukraine alone the accident could have resulted in an estimated 200,000 additional deaths in the period between 1990 and 2004.”
The Hyatt Regency Walkway Collapse (1981)

- On July 17, 1981, approximately 2000 people were gathered to watch a dance contest in the brand new Hyatt Regency Hotel in Kansas City.
- The Walkway collapse has killed 114 people and injured more than 200 others.
- The Missouri Board of Architects, Professional Engineers, and Land Surveyors convicted the engineers employed by Jack D. Gillum and Associates of gross negligence, misconduct, and unprofessional conduct in the practice of engineering; they all lost their engineering licenses in the states of Missouri and Texas and their membership to ASCE. While Jack D. Gillum and Associates itself was cleared of criminal negligence, it was stripped of its license to be an engineering firm.

Design Tools and Resources

- Computational Tools
  - CAD – AutoCAD, Unigraphics, Solid Works
  - CAE – ANSYS, NASTRAN & ABAQUS
  - CAM
- Acquiring Technical Information
  - Libraries
  - Government Sources – US Patent office, NIST etc.
  - Professional Societies – ASME, SAE, SME
  - Commercial vendors
  - Internet

Interaction Between Design Process Elements

- Design Consideration
  - Functionality
  - Strength/Stress
  - Distortion/deflection/stiffness
  - Friction, Wear, Corrosion
  - Safety, Reliability
  - Manufacturability
  - Marketability
  - Shape, Size, etc

- Traditional Approach
  - Design for Manufacturing,
  - Design for Assembly
  - Concurrent Engineering

Design Tools and Resources

- Computational Tools
  - CAD – AutoCAD, Unigraphics, Solid Works
  - CAE – ANSYS, NASTRAN & ABAQUS
  - CAM
- Acquiring Technical Information
  - Libraries
  - Government Sources – US Patent office, NIST etc.
  - Professional Societies – ASME, SAE, SME
  - Commercial vendors
  - Internet

Interaction Between Design Process Elements

- Design Consideration
  - Functionality
  - Strength/Stress
  - Distortion/deflection/stiffness
  - Friction, Wear, Corrosion
  - Safety, Reliability
  - Manufacturability
  - Marketability
  - Shape, Size, etc

- Traditional Approach
  - Design for Manufacturing,
  - Design for Assembly
  - Concurrent Engineering

Design Tools and Resources

- Computational Tools
  - CAD – AutoCAD, Unigraphics, Solid Works
  - CAE – ANSYS, NASTRAN & ABAQUS
  - CAM
- Acquiring Technical Information
  - Libraries
  - Government Sources – US Patent office, NIST etc.
  - Professional Societies – ASME, SAE, SME
  - Commercial vendors
  - Internet

Interaction Between Design Process Elements

- Design Consideration
  - Functionality
  - Strength/Stress
  - Distortion/deflection/stiffness
  - Friction, Wear, Corrosion
  - Safety, Reliability
  - Manufacturability
  - Marketability
  - Shape, Size, etc

- Traditional Approach
  - Design for Manufacturing,
  - Design for Assembly
  - Concurrent Engineering

Design Tools and Resources

- Computational Tools
  - CAD – AutoCAD, Unigraphics, Solid Works
  - CAE – ANSYS, NASTRAN & ABAQUS
  - CAM
- Acquiring Technical Information
  - Libraries
  - Government Sources – US Patent office, NIST etc.
  - Professional Societies – ASME, SAE, SME
  - Commercial vendors
  - Internet

Interaction Between Design Process Elements

- Design Consideration
  - Functionality
  - Strength/Stress
  - Distortion/deflection/stiffness
  - Friction, Wear, Corrosion
  - Safety, Reliability
  - Manufacturability
  - Marketability
  - Shape, Size, etc

- Traditional Approach
  - Design for Manufacturing,
  - Design for Assembly
  - Concurrent Engineering

Design Tools and Resources

- Computational Tools
  - CAD – AutoCAD, Unigraphics, Solid Works
  - CAE – ANSYS, NASTRAN & ABAQUS
  - CAM
- Acquiring Technical Information
  - Libraries
  - Government Sources – US Patent office, NIST etc.
  - Professional Societies – ASME, SAE, SME
  - Commercial vendors
  - Internet

Interaction Between Design Process Elements

- Design Consideration
  - Functionality
  - Strength/Stress
  - Distortion/deflection/stiffness
  - Friction, Wear, Corrosion
  - Safety, Reliability
  - Manufacturability
  - Marketability
  - Shape, Size, etc

- Traditional Approach
  - Design for Manufacturing,
  - Design for Assembly
  - Concurrent Engineering

Table 1.3 SI units and prefixes.
Conversion Factors

<table>
<thead>
<tr>
<th>Unit</th>
<th>English</th>
<th>Exact SI</th>
<th>Approximate SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>1 in.</td>
<td>0.0254 m</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>1 lbm</td>
<td>0.45359237 kg</td>
<td>0.454 kg</td>
</tr>
<tr>
<td>Temperature</td>
<td>1 deg R</td>
<td>5.55 K</td>
<td></td>
</tr>
</tbody>
</table>

(b) Definitions

- **Acceleration of gravity** $g = 9.8066 m/s^2 (32.174 ft/s^2)
- **Energy** \( \text{ft} \cdot \text{lb} = \text{in} \cdot \text{lb} \cdot \text{ft} \). \( 1 \text{ in} \cdot \text{lb} \cdot \text{ft} = 778.16 \text{ ft-lbf} \)
- **Kinetic energy** \( KE = \frac{1}{2}mv^2 \)
- **Potential energy** \( PE = mgh \)
- **Pressure** \( \text{lb/in}^2 \)
- **Temperature** $T = \frac{5}{9}C + 32$ (where $C$ is degrees Celsius)
- **Density** $\rho = \frac{m}{V}$
- **Kinematic viscosity** $\nu = \frac{\mu}{\rho}$
- **Volume** $1 \text{ cubic foot} = 7.48 \text{ gal}$

(c) Useful conversion factors

- $1 \text{ in.} = 0.0254 \text{ m}$
- $1 \text{ lb} = 4.446 \text{ N}$
- $1 \text{ lb} = 980.6 \text{ N}$
- $1 \text{ lb/ft}^2 = 1450 \text{ Pa}$
- $1 \text{ lb-in} = 6.99 \text{ MPa}$
- $1 \text{ lb-in} = 850 \text{ J}$
- $1 \text{ lb-ft} = 1.356 \text{ J}$
- $1 \text{ hp} = 746 \text{ W} = 25.45 \text{ Btu/hr}$
- $1 \text{ kW} = 8414 \text{ Btu/hr}$
- $1 \text{ Btu/hr} = 0.001056 \text{ m}^2 \cdot \text{ K}$
- $1 \text{ cal} = 9.48 \text{ Btu}$

(d) **Design for Manufacture (DFM)**

- **An approach to design that emphasizes the importance of easy manufacturing, service, and maintenance that typically decreases a product’s total cost while increasing its quality, reliability, and delivery time.**

- **Some general principles of DFM**
  - Minimize the number of parts: Combine adjacent parts when possible (Biggest source of cost reduction)
  - Utilize standard components whenever possible (standard fasteners, bearings, etc.)
  - Create modular designs: Offer variant designs built on the same platform
  - Utilize parts that fulfill dual purposes
  - Use the same parts in numerous products
  - Use the roughest possible surfaces with the largest possible tolerances
  - Avoid secondary operations such as Heat treatment and Painting
  - Specify the cheapest material that will work
  - Design for production volume
  - Minimize separate fasteners
  - Integrated washers
  - Minimize handling

- **References**

---

**Invisalign Product**

The Invisalign® product. (a) An example of an Aligner; (b) a comparison of conventional orthodontic braces and a transparent Aligner.

**Invisalign**

The process used in application of Invisalign orthodontic treatment.

(a) Impressions are made of the patient’s teeth by the orthodontist, and shipped to Align technology, Inc. These are used to make plaster models of the patient’s teeth.

(b) High-resolution three-dimensional representations of the teeth are produced from the plaster models. The correction plan is then developed using computer tools.

(c) Rapid-prototyped molds of the teeth at incremental positions are produced through stereolithography.

(d) An Aligner, produced by molding a transparent plastic over the stereolithography part. Each Aligner is worn approximately two weeks. The patient is left with a healthy bite and a beautiful smile.
Design for Assembly (DFA)

- DFA is a specific area of DFM that suggests consideration of assembly processes during design.
  - Assembly typically up to 50% of the manufacturing time.
  - Assembly: Materials handling, Actual assembling & Quality Control
- Some general principles of DFA
  - Minimize the number of parts
  - Minimize assembly operations
  - Assemble parts from one direction: Build of a primary part
  - Allow for part variations
  - Facilitate part transportation: Assemble lighter parts on heavier parts
  - Avoid orienting parts
  - Facilitate the orientation of parts: Avoid Tangling & Obvious asymmetries
  - Select an appropriate assembly method: Avoid unnecessary threaded fasteners
  - Facilitate insertion
    - Rounded corners, Chamfers, Tapered hubs, Elongated holes etc.

Dimensions, Tolerance and Related Attributes

- Dimensions – ‘a numerical value expressed in appropriate units of measure and indicated on a drawing along with lines, symbols and notes to define the size/ geometric characteristics of a part’
  - How well the parts of a product fits together.
- Variations in the part size comes from manufacturing processes. Why?
- Tolerance – Allowable variation in dimension.
- Surface – affects product performance, esthetic and ‘wear’
Other Geometric Attributes

- Angularity
- Circularity
- Concentricity
- Cylindricity
- Flatness
- Parallelism
- Perpendicularity
- Roundness
- Squareness
- Straightness