Basic Actions of Design Problem Solving

• ESTABLISH the need or realize that there is a problem to be solved.
  – New needs also can be established throughout the design effort because new design problems arise as the product evolves. Design of these details poses new subproblems.
• PLAN how to solve the problem.
  – Planning occurs mainly at the beginning of a project. Plans are always updated because understanding is improved as the process progresses.
• UNDERSTAND the problem by developing requirements and uncovering existing solutions for similar problems.
  – Formal efforts to understand new design problems continue throughout the process. Each new subproblem requires new understanding.
• GENERATE alternative solutions.
  – Concept Generation vs. Product Generation
• EVALUATE the alternatives by comparing them to the design requirements and to each other.
  – Evaluation techniques also depend on the design phase; there are differences between the evaluation techniques used for concepts and those used for products.
• DECIDE and acceptable solutions
  – Decision making requires a commitment based upon incomplete evaluation.
  – Decision requires a consensus of team members.
• COMMUNICATE the results
  – Communication of the information developed to others on the design team and to management is an essential part of concurrent design.
Basic Terminologies used to describe the Design Process

• “Communication” as a one key feature of concurrent engineering
  – Communication depends on a shared understanding of terminology.

• Function:
  – What a product or a system is supposed to do;
  – Described using action verbs and a noun describing the object on which the action occurs:
    • Record images; quantify the blood pressure; fix an unstable spine segment; etc.

• System:
  – A grouping of objects that perform a specific function;
    • Shutter system; timer system; CD-R system; cooling system; etc.
  – A system can be decomposed into another subsystems or further into individual components (or parts).
  – Multiple systems can be assembled into a higher level system or further into a final product.

• Feature: the important form and function aspects of mechanical devices
  • dimensions, material properties, shapes, or functional details (speed of opening and closing for shutter system)

In general, during the design process, the function of the system and its decomposition are considered first. After the function has been decomposed to the finest subsystems possible, assemblies and components are developed to provide these functions.
Function, Behavior, and Performance

- **Function:**
  - describes what a device does.
  - But, function provides no information about how a device accomplishes the function.

- **Form:**
  - The term “form” relates to any aspect of physical shape, geometry, construction, material, or size.
  - provides some information on how a device accomplishes the function.

- **Behavior and Performance in association with Function.**
  - Function is the desired output from a system yet to be designed.
  - Behavior is the actual output, the response of the system’s physical properties to the input energy or control.
  - Performance is the measure of function and behavior – how well the device does what it is designed to do.
  - A clear picture of desired performance should be developed in the beginning of the design process.
Types of Mechanical Design Problems

- Selection Design:
  - choosing one item (or more) from a list of similar items
  - choosing a bearing, bolt, motor, etc. from a catalog
- Configuration Design:
  - How to assemble all the components into the completed product
- Parametric Design:
  - Finding values for the features that characterize the object being studied or that meet the requirements
  - Design a cylindrical tank: \( V = \pi r^2 l \), determine \( r \) and \( l \) for known \( V \)
- Original Design:
  - Design a process, assembly or component not previously in existence
- Redesign:
  - Redesign of an existing product
  - Most design problems are redesign problems since they are based on prior, similar solutions. Conversely, most design problems are original as they contain something new that makes prior solutions inadequate.
Languages of Mechanical Design

A mechanical object can be described by:

• Semantic language:
  – Verbal or textual representation of the object
  – “bolt” or “The shear stress is equal to the shear forces on the bolt divided by the x-sectional area.”

• Graphical language:
  – drawing of the object
  – Sketches, scaled representations of orthogonal drawings, or artistic renderings

• Analytical Language:
  – Equation, rules, or procedures representing the form of function of the object
  – \( \tau = \frac{F}{A} \)

• Physical Language:
  – Hardware or physical model of the project

- In most cases, the initial need is expressed in a semantic language as a written specification or a verbal request by a customer or supervisor, and the final result of the design process is a physical product.
Constraints, Goals and Design Decision

• The design progresses in increment punctuated by design decisions.
• Design State:
  – Collection of all the knowledge, drawings, models, analyses and notes thus far generated
  – In the beginning, design state is just the problem statement
• Design Constraints:
  – Factors limiting the design process
    • Examples: size, strength of material, corrosion properties, anatomy, etc.
  – In the beginning, the design requirements effectively constrains the possible solutions to a subset of all possible product designs.
  – Two sources of constraints added during the design process:
    • Designer’s knowledge of mechanical devices and the specific problem being solved
    • Result of design decisions
• Design Decision:
  – Continuous comparison between design state and the goal (requirements for the product given in the problem statement)
    • The difference controls the process.
  – Design is the successive development and application of constraints until only one unique products remains.
  – Each design decision changes the design state.
*The most valuable information is the decisions that are communicated to others.
Design as Refinement of Abstract Representations

See Table 2.2 for levels of abstraction in other languages.

Graphical Refinement