2. Mechanical Design Problems and Process

- Concurrent engineering relies on communication
- Communication depends on a shared understanding of terminology
- Define some of the terminologies that we should be using in this course.

Decomposition of Mechanical Systems

- Mechanical – Parts and assemblies all mechanical in nature
- Electromechanical – mechanical and electronic
- Mechatronics – mechanical, electronic and software
Decomposition of Mechanical Systems

- Decomposing a product by parts is great for manufacturing, but design focuses on function
- Example of a mechatronic system – Automatic Camera and its shutter assembly

Fig. 2-1
A Kodak Cameo 300M zoom camera

Fig. 2-2
The shutter assembly
Decomposition of Mechanical Systems

- A system is a grouping of objects that perform a specific function
- Camera – is a photographic system to record images
- Shutter – control light coming through the lens
- Exposure system – auto focus system, light meter, controller and shutter system

Decomposition of Design disciplines

- Assemblies – Parts or Components
- Function of the system is decomposed first
- For the finest subsystems – develop components and assemblies

Fig. 2-3 Decomposition of design disciplines

Product function and behavior

- Function, Operation and purpose are used synonymously in relation to mechanical components
- Screw driver
- Handlebar of a bicycle
  - Steer the bicycle
  - Support the rider
  - Support the brake lever
  - Transform the gripping force

Product function and behavior

- Handlebar of a bicycle
  - Is apart of a number of assemblies in performing all those functions
- In mechanical systems form enables function, and function determines form

Fig. 2-4 Function and behavior

(a) Function

(b) Behavior

Function and behavior

- Function is the desired output
- Behavior is the actual output
- Performance is the measure of function and behavior

Mechanical Design Problems

- There a number of approaches to design
- Selection design
  - Correct bearing from a catalog
- Configuration design
- Parametric design
- Original design
- Redesign

Selection design

- Choosing an item from a list of similar items
- Use catalogs
Fig. 2-5
Load on a shaft

Using catalogs identify all the bearings that satisfy the requirements

Table 2.1: Potential bearings for a shaft

<table>
<thead>
<tr>
<th>Type</th>
<th>Diameter (mm)</th>
<th>Width (mm)</th>
<th>Load rating (kN)</th>
<th>Speed limit (rpm)</th>
<th>Catalog number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design groove ball bearing</td>
<td>12</td>
<td>14</td>
<td>1500</td>
<td>11,000</td>
<td>10030</td>
</tr>
<tr>
<td>Design SLA</td>
<td>27</td>
<td>16</td>
<td>2000</td>
<td>15,000</td>
<td>15030</td>
</tr>
<tr>
<td>Angular contact ball bearing</td>
<td>19</td>
<td>12</td>
<td>5000</td>
<td>20,000</td>
<td>20030</td>
</tr>
<tr>
<td>Roller bearing</td>
<td>47</td>
<td>16</td>
<td>3000</td>
<td>15,000</td>
<td>72204</td>
</tr>
<tr>
<td>Needle bearing</td>
<td>24</td>
<td>14</td>
<td>3000</td>
<td>15,000</td>
<td>15030</td>
</tr>
<tr>
<td>Nylon bushing</td>
<td>23</td>
<td>Variable</td>
<td>200</td>
<td>10</td>
<td>4030</td>
</tr>
</tbody>
</table>

Configuration design

- Packaging design
- Subsystems are fully designed
- For example, Computer sub systems
Parametric design

- Use design equations, to get the solutions
- Design a cylindrical tank with a volume of 4 m³
  - Volume = \( \pi r^2 l = 4 \)
  - \( r \) = radius of the tank
  - \( l \) = height of the tank

Original design

- Entirely new
Redesign

- Improvement or modification of an existing design
- Most design problems are redesign since they are based on prior, similar solutions. Conversely, most problems are original as they contain something new that makes prior solutions inadequate.

Bicycle design is well advanced by the end of 19th century. Not much changes since then in the conventional bike design

Fig. 2-7 1890 Humber bicycle

Languages of Mechanical Design

- Semantic: verbal presentation
- Graphical: drawing of the object
- Analytical: equations, rules, etc.
- Physical: hardware of the object
**Design Refinement**

- The process of making an object less abstract is called refinement
Fig. 2-12
Abstract sketch and final drawing of a component

Table 2.2 Levels of abstraction in different languages

<table>
<thead>
<tr>
<th>Language</th>
<th>Abstract</th>
<th>Level of abstraction</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic</td>
<td>Qualitative words (e.g., long, fast, light)</td>
<td>Reference to specific parameters or components</td>
<td>Reference to the values of the specific parameters or components</td>
</tr>
<tr>
<td>Graphical</td>
<td>Rough sketches</td>
<td>Scale drawings</td>
<td>Solid models with tolerances</td>
</tr>
<tr>
<td>Analytical</td>
<td>Qualitative relations (e.g., left of)</td>
<td>Back-of-the-envelope calculations</td>
<td>Detailed analysis</td>
</tr>
<tr>
<td>Physical</td>
<td>None</td>
<td>Models of the product</td>
<td>Final hardware</td>
</tr>
</tbody>
</table>

Table 2.3 Levels of abstraction in describing a bolt

<table>
<thead>
<tr>
<th>Language</th>
<th>Abstract</th>
<th>Level of abstraction</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic</td>
<td>A bolt</td>
<td>A short bolt</td>
<td>A 1” 14-20 UNC Grade 5 bolt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of bolt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Body of bolt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of element threaded</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Right-hand rule</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\tau = F/A$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\tau = F/A$</td>
<td></td>
</tr>
</tbody>
</table>

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Nageswara Rao Posinasetti
Summary

- Decomposing a product by its form (i.e. components and assemblies) is great for manufacturing and assembly, but design focuses on function.
- Form enables function and function underlies form.

Summary

- 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.
- Design is the technical and social evolution of information punctuated by decision-making.

Questions and Comments