INTRODUCTION

- WHAT?
- WHY?
- HOW?

+ Homework
  Rules by Davin
TABLE 1.6-1 The matrix of combinations of material classes and property classes discussed in most introductory materials engineering courses.

<table>
<thead>
<tr>
<th>Property Class</th>
<th>Materials Class</th>
<th>Ceramics</th>
<th>Polymers</th>
<th>Semiconductors</th>
<th>Composites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>Static</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Dynamic</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
</tr>
<tr>
<td>Thermal</td>
<td>Thermal</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
<td>XXXXXX</td>
</tr>
</tbody>
</table>

TABLE 1.5-1 Conductivities of some common materials at room temperature.

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity (mhos/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>High</td>
</tr>
<tr>
<td>Ceramic</td>
<td>Low</td>
</tr>
<tr>
<td>Polymer</td>
<td>Medium</td>
</tr>
<tr>
<td>Composite</td>
<td>Low</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>Medium</td>
</tr>
<tr>
<td>Microchannel</td>
<td>Low</td>
</tr>
</tbody>
</table>

Metal in an complicated, ceramic and due to
Lecture 1 ME 23

Case Study: The Hammer

Components

\[ \theta = E \cdot \varepsilon \]

Hooke's Law

\[ \varepsilon = \frac{\Delta L}{L_0} \]

Materials of Construction:

Substances out of which a thing is made

Properties:

Prop. is a matrix, size and shape, independent response to an external stimulus.

Not all properties are quantifiable, some are subjective, such as the "feel" and "optical appearance".
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>MATERIAL</th>
<th>PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>HERO</td>
<td>STEEL (FERROUS) ALLOY</td>
<td>HEAVY - HIGH DENSITY</td>
</tr>
<tr>
<td>SHAFT</td>
<td>GFRP</td>
<td>HARDNESS</td>
</tr>
<tr>
<td></td>
<td>FIBERGLASS</td>
<td>STRENGTH</td>
</tr>
<tr>
<td></td>
<td>COMPOSITE MATERIAL</td>
<td>IMPACT RESISTANCE</td>
</tr>
<tr>
<td>GRIP</td>
<td>ELASTOMER</td>
<td>TENSILE STRENGTH</td>
</tr>
<tr>
<td></td>
<td>RUBBER</td>
<td>LOW DENSITY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STIFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FRACURE RES.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TUMBLE RES.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FRICTION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMFORTABLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ERGONOMICALLY DESIGNED</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WETTING</td>
</tr>
<tr>
<td>Joints</td>
<td>EPOXY RESIN</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SURFACE TREATMENT</td>
<td>POLYURETHANE</td>
<td>CORROSION INHIBITOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AESTHETICS</td>
</tr>
</tbody>
</table>
Fig. 27.1. Design methodology.
DESIGN PRINCIPLES

(1) "ECONOMIC" DESIGN

- Design factors intended to maximize productivity by reducing operator fatigue.
- Grip fits snugly into hand and has shock absorbing qualities.

\[ E(t) = \frac{1}{E_0} \frac{1}{E(t)} \]

Time Dep. Deformation

- Temp.

Material Choice: Thermo Plastic Elastomer

Can be produced by injection molding...
SHAFT NEEDS TO BE STIFF, PEI LIGHT AND FRACTURE RESISTANT.

\[ \delta_2 = \frac{FL^3}{3EI} \]

\[ I = \frac{h^3 w}{12} \]

\[ \delta_2 \approx \frac{1}{h^3} \]
PERFORMANCE: SUITABILITY FOR A SPECIFIC TASK

(a) MINIMIZE WEIGHT OF SHAFT

Figure of Merit

\[ S_2, L, W, h \] FIXED

\[ S_2 = \frac{4F \cdot L^3 \cdot L^3 \cdot W^3 \cdot S^3}{E \cdot W \cdot m^3} \]

\[ m = \left( \frac{4F \cdot L^3 \cdot L^3 \cdot W^3 \cdot S^3}{E \cdot W \cdot S_2} \right)^{\frac{1}{3}} = C \cdot \left( \frac{S}{E^{1/3}} \right) \]

UNIT WEIGHT

MATERIAL STIFFNESS

Minimize Figure of Merit To Minimize Shaft Weight

USE ANG. MATHS DATABASE.
TABULATED VALUES SUGGEST:

(1) **HIGH MODULUS CARBON FIBER/EPoxy COMPOSITE**
   - **VERY LIGHT, VERY STIFF.**
   - **VERY EXPENSIVE!**

(2) **WOOD**
   - **UNPREDICTABLE**

(3) **E-GLASS/EPoxy COMPOSITE**
   - **BIT HEAVIER THAN CARBON COMP.**
   - **CHEAPER!**

(4) **HIGH FRACTURE RESISTANCE**

*Shaft: Avoid "Breiz" fracture*

→ **FRACTURE MECHANICS CAN GIVE SOME DESIGN GUIDELINES**

\[ \sigma_{m} = \sigma_0 \left( \frac{a}{r^2} \right)^{1/2} \]

→ **NOTCHES ARE STRESS CONCENTRATORS.**

Fibers in handle are ideal for arresting propagating cracks.
(C) DIFFERENTIATED MECHANICAL PROPERTIES IN HAMMER HEAD

SPIKE FACE: HARD BUT NOT BRITTLE
BODY: TOUGH, IMPACT STRENGTH.

STEEL IS GOOD MATERIAL FOR THE HEAD

But what type of steel?

FERROUS ALLOY: IRON, CARBON COMPOSITION AND (Ni, Cr, ...)

HISTORY

SPIKE FACE AND BODY SHOULD BE MADE FROM ONE, SINGLE PIECE

A TYPICAL STEEL FOR HAMMER HEADS:

MEDIUM-CARBON FORGING STEEL
(HYPO-EUTECTIC, i.e. \( C < 0.8\% \))

0.5 - 0.6 \% C
0.5 - 0.9 \% Mn
0.1 - 0.4 Si
How is a hammer head produced?

Shaped by **hot forming** and slow cool

\[ \rightarrow \text{EQUILIB. STRUCTURE} \]

Then heated above eutectic temperature ( ) to bring out FeC (equiaxed \( \gamma \)-crystals). Rapid quench bypasses the eutectic reaction and a non-equilibrium grain structure is "frozen in" (MARTENSITE)

If necessary, the martensitic structure can be "tempered" by heat treatment.

Doctium \( \uparrow \)

Hardness \( \uparrow \) \( \downarrow \)
Figure 3.11 Microstructures during slow cooling from the austenite region of (a) a eutectoid steel, (b) a hypoeutectoid steel, (c) a hypereutectoid steel.