INTRODUCTION

- WHAT?
- WHY?
- HOW?

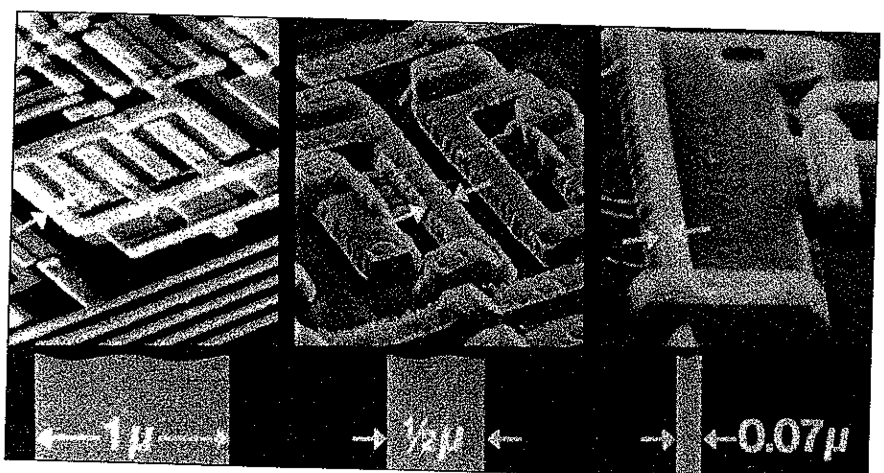
+ HOMEWORK
RULES BY DAVID

TABLE 1.6–1 The matrix of combinations of material classes and property classes discussed in most introductory materials engineering courses.

Property class	Materials class				
	Metals	Ceramics	Polymers	Semiconductors	Composites
Mechanical	XXXX	XXXX	XXXX	XXXX	XXXX
Electrical	XXXX	XXXX	XXXX	XXXX	XXXX
Dielectric and optical	XXXX	XXXX	XXXX	XXXX	XXXX
Magnetic	XXXX	XXXX	XXXX	XXXX	XXXX
Thermal	XXXX	XXXX	XXXX	XXXX	XXXX
Environmental interaction	XXXX	XXXX	XXXX	XXXX	XXXX

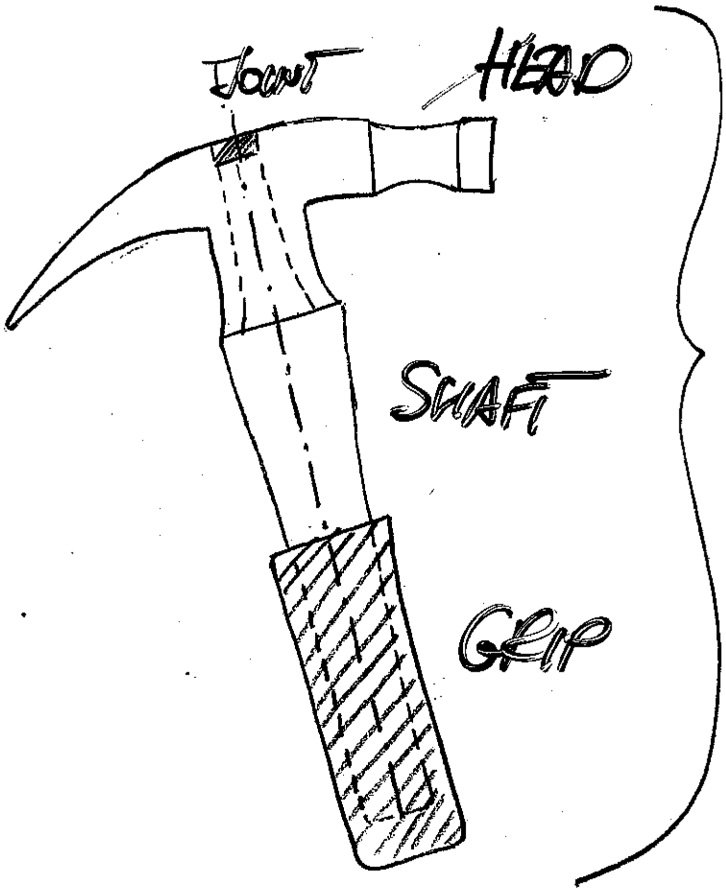
TABLE 1.5–1 Conductivities of some common materials at room temperature.

Material	Conductivity $[(\Omega\text{-m})^{-1}]$
Metals	
Cu	6.0×10^7
Ag	6.8×10^7
Al	3.8×10^7
Ceramics	
Al_2O_3	10^{-12}–10^{-10}
Porcelain	10^{-12}–10^{-10}
Polymers	
Polyethylene	10^{-17}–10^{-13}
Polystyrene	$< 10^{-14}$
Polyacetylene doped with AsF_5	10^5
Semiconductors	
Si (pure)	4×10^{-4}
Si (2×10^{-14} at.% P)	2240
Ge (pure)	2.2



LECTURE 1 ME 83

CASE STUDY: THE HAMMER



COMPONENTS

$$\sigma = E \cdot \varepsilon$$

HOOKES' LAW

$$\sigma = \frac{F}{A}$$

$$\varepsilon = \frac{\Delta l}{l_0}$$

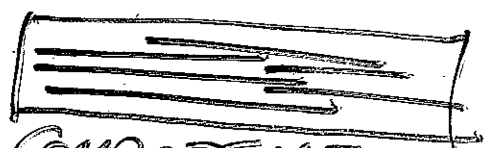
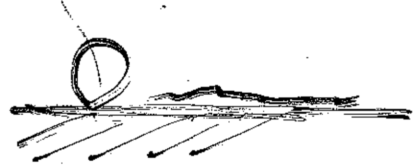
MATERIALS OF CONSTRUCTION:

SUBSTANCES OUT OF WHICH A THING IS MADE

PROPERTIES:

PROP. IS A MATLS. SIZE AND SHAPE INDEPENDENT RESPONSE TO AN EXTERNAL STIMULUS.

NOT ALL PROPERTIES ARE QUANTIFIABLE, SOME ARE SUBJECTIVE, SUCH AS THE "FEEL" AND "OPTICAL APPEARANCE".

COMPONENT	MATERIAL	PROPERTIES
HEAD	STEEL (FERROUS ALLOY)	HEAVY → HIGH DENSITY HARDNESS STRENGTH IMPACT RESISTANCE
SHAFT	GFRP FIBERGLASS  COMPOSITE MATL.	TENSILE STRENGTH LOW DENSITY STIFF FRACTURE RES.
GRIP	ELASTOMER → RUBBER	VIBRAT. RES. FRICTION 'COMFORTABLE' → 'ERGONOMICALLY' DESIGNED
JOINT	EPOXY RESIN 	WETTING
SURFACE TREATMENT	POLYURETHANE	CORROSION INHIBITOR AESTHETICS

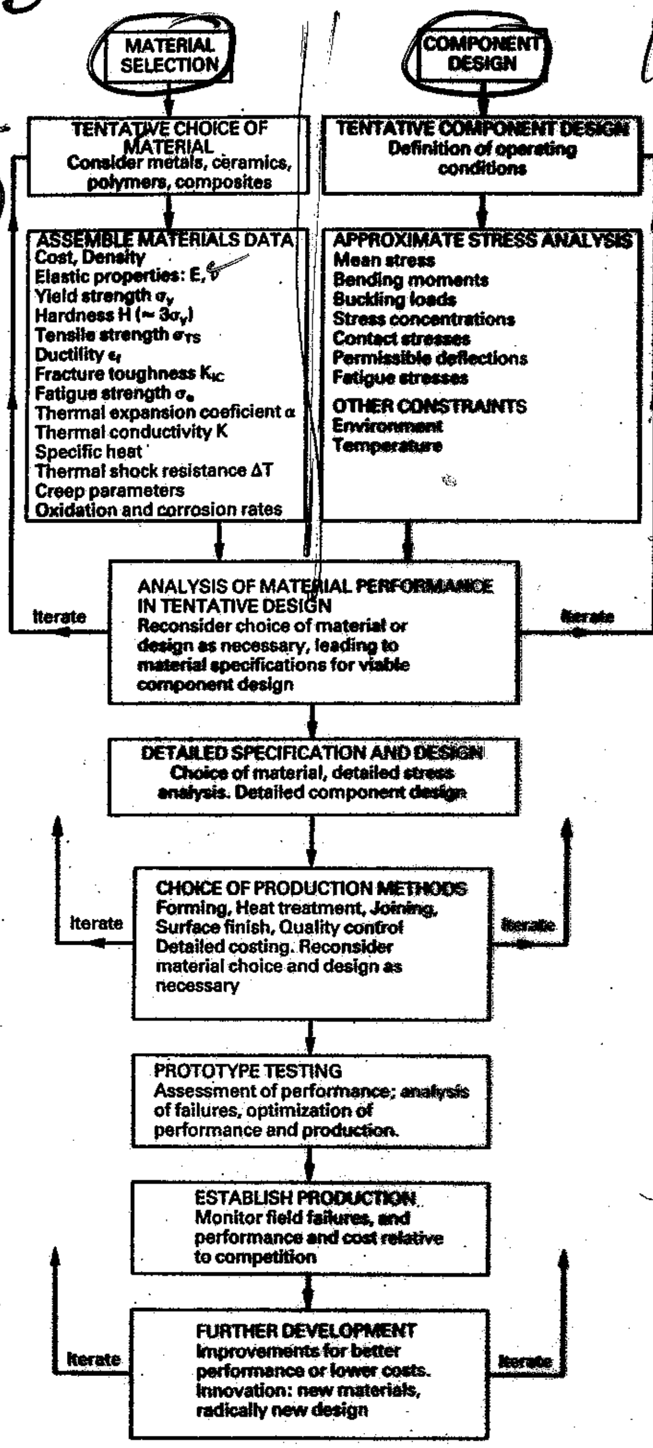


Fig. 27.1. Design methodology.

DESIGN PRINCIPLES

(1) "ERGONOMIC" DESIGN

▷ DESIGN FACTORS INTENTED TO MAXIMIZE PRODUCTIVITY BY REDUCING OPERATOR FATIGUE + DISCOMFORT

GRIP FITS SNUGGLY INTO HAND AND HAS SHOCK ABSORBING QUALITIES.

$$\underline{E_{(t)}} = \sigma_0 \cdot \frac{1}{\underline{\varepsilon_{(t)}}}$$ } TIME DEP. DEFORMATION

POLYMERS: RATE DEP. MECH. PROP.
TEMP. " " "

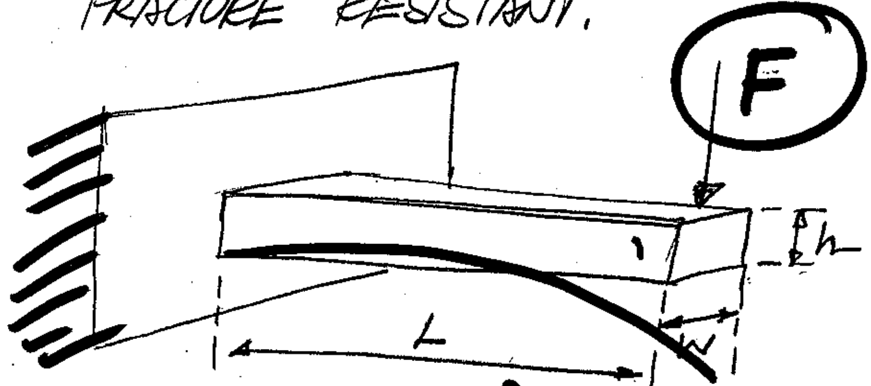
MATERIAL CHOICE: THERMO PLASTIC ELASTOMER

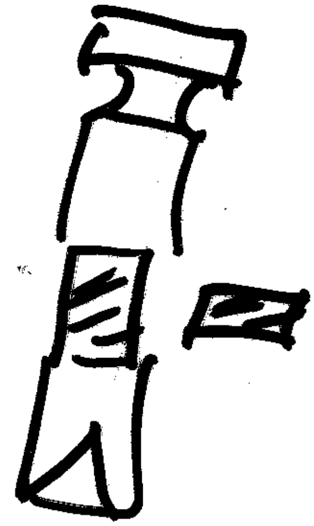
CAN BE PRODUCED BY

INJECTION MOLDING

(2) MECHANICAL AND STRUCTURAL DESIGN

SHAFT NEEDS TO BE STIFF, REL. LIGHT AND FRACTURE RESISTANT.





$$\delta_2 = \frac{F\cdot L^3}{3E\cdot I}$$

I — AREA MOM. OF INERTIA

$$I = \frac{h^3\cdot w}{12}$$

$$\delta_2 = \frac{4F\cdot L^3}{E\cdot h^3\cdot w}$$

$$\delta_2 \sim \frac{1}{h^3}$$

$$\frac{F}{A_0} = \sigma = E\cdot\frac{\Delta l}{l_0}$$

↳ PERFORMANCE CONSIDERATIONS

↳ MATERIALS SELECTION "

↳ PERFORMANCE: **SUITABILITY FOR A SPECIFIC TASK**

(a) MINIMIZE WEIGHT OF SHAFT

FIGURE OF MERIT $= \dfrac{\text{MATERIAL STIFFNESS}}{\text{UNIT WEIGHT}}$

δ_z, l, w, h } FIXED GEOMETRIC PROPERTIES

$$\rho = \frac{m}{V} \; ; \; V = l \cdot w \cdot h \; ; \; \rho, h \; !$$

$$h = \frac{m}{l \cdot w \cdot \rho}$$

$$\delta_z = \frac{4F \cdot l^3 \cdot l^3 \cdot w^3 \cdot \rho^3}{E \cdot w \cdot m^3}$$

$$m = \left(\frac{4 \cdot F \cdot l^3 \cdot l^3 \cdot w^3 \cdot \rho^3}{E \cdot w \cdot \delta_z} \right)^{1/3} = C \cdot \left(\frac{\rho}{E^{1/3}} \right)$$

MINIMIZE FIGURE OF MERIT TO MINIMIZE SHAFT WEIGHT

↳ USE ENG. MATLS DATABASE!

TABULATED VALUES SUGGEST:

(1) HIGH MODULUS CARBON FIBER/EPOXY COMPOSITE
VERY LIGHT, VERY STIFF:
VERY EXPENSIVE!

(2) WOOD
UNPREDICTABLE

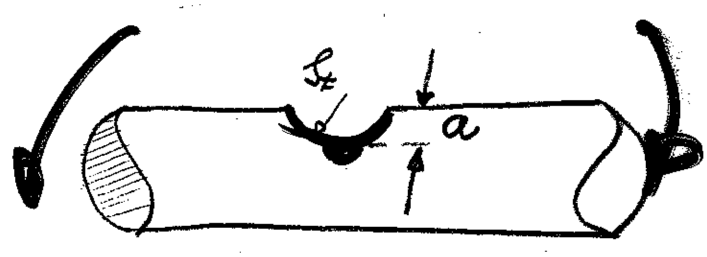
(3) E-GLASS/EPOXY COMPOSITE
BIT HEAVIER THAN CARBON COMP.
CHEAPER!

(b) HIGH FRACTURE RESISTANCE

SHAFT: **AVOID "BRITTLE" FRACTURE**

→ FRACTURE MECHANICS CAN GIVE SOME DESIGN GUIDELINES

$$\sigma_m = \sigma_0 \cdot 2 \left(\frac{a}{\rho_t} \right)^{1/2}$$



→ **NOTCHES ARE STRESS CONCENTRATORS.**

FIBERS IN HANDLE ARE IDEAL FOR ARRESTING PROPAGATING CRACKS.

(C) DIFFERENTIATED MECHANICAL PROPERTIES IN HAMMER HEAD

STRIKE 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 (Ni, Cr, ...)

COMPOSITION AND HISTORY

STRIKE FACE AND BODY SHOULD BE MADE FROM ONE, SINGLE PIECE ⇒

A TYPICAL STEEL FOR HAMMER HEADS:

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

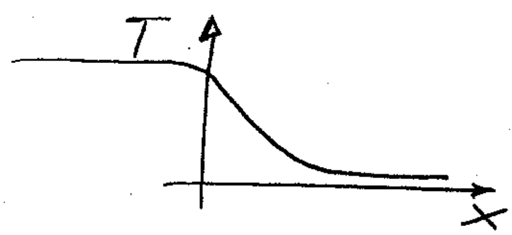
0.5 - 0.6 % C
0.5 - 0.9 % Mn
0.1 - 0.4 Si

HOW IS A HAMMER HEAD PRODUCED? 

SHAPED BY **HOT FORMING** AND SLOW COOL

⟶ **EQUILIB. STRUCTURE**

THEN HEATED ABOVE EUTECTIC TEMPERATURE ( ) TO BRING OUT FCC IRON (EQUIAXED γ-CRYSTALS). RAPID QUENCH BY-PASSES THE EUTECTIC REACTION AND A NON-EQUILIBRIUM GRAIN STRUCTURE IS "FROZEN IN" (**MARTENSITE**



IF NECESSARY, THE MARTENSITIC STRUCTURE CAN BE "TEMPERED" BY HEAT TREATMENT.

DUCTILITY ↑

HARDNESS ↓

PHASE DIAG.

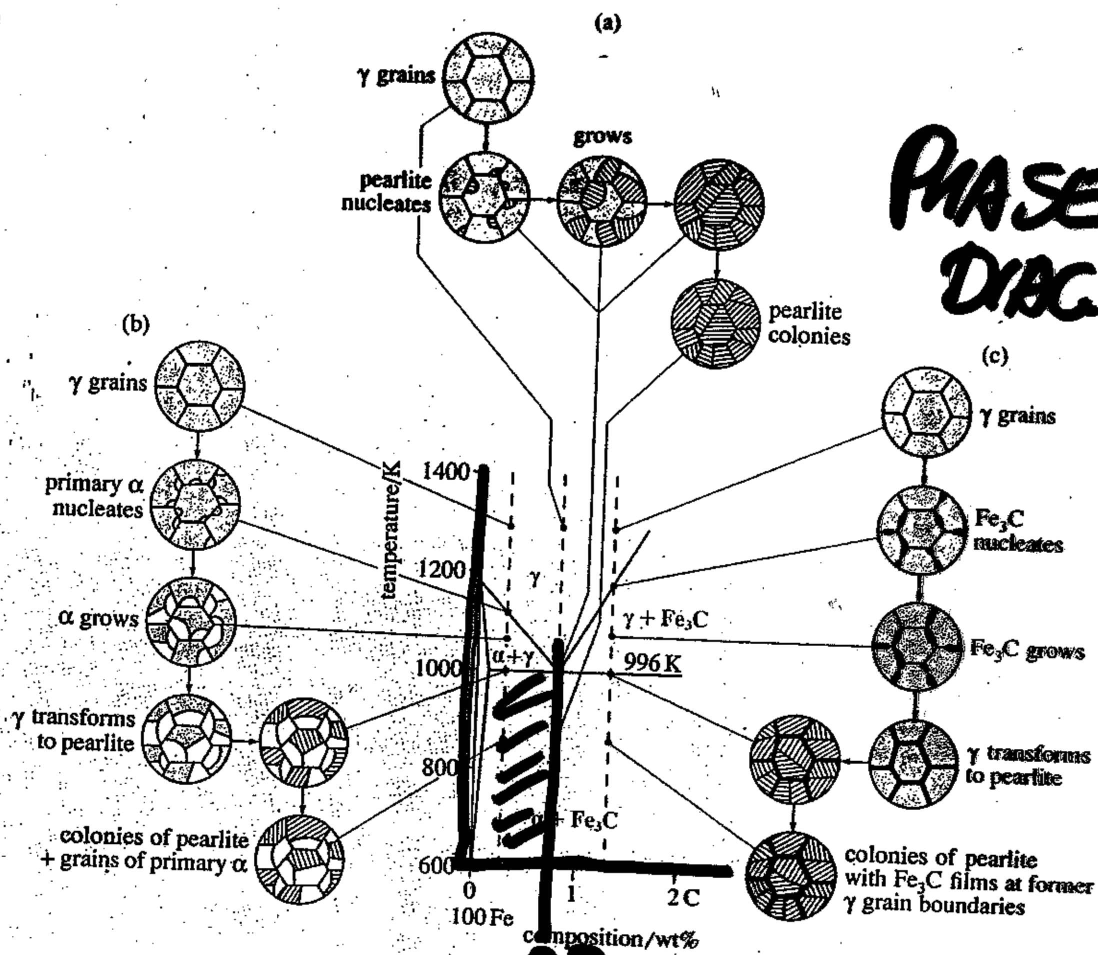


Figure 3.11 Microstructures during slow cooling from the austenite region of (a) a eutectoid steel, (b) a hypoeutectoid steel, (c) a hypereutectoid steel