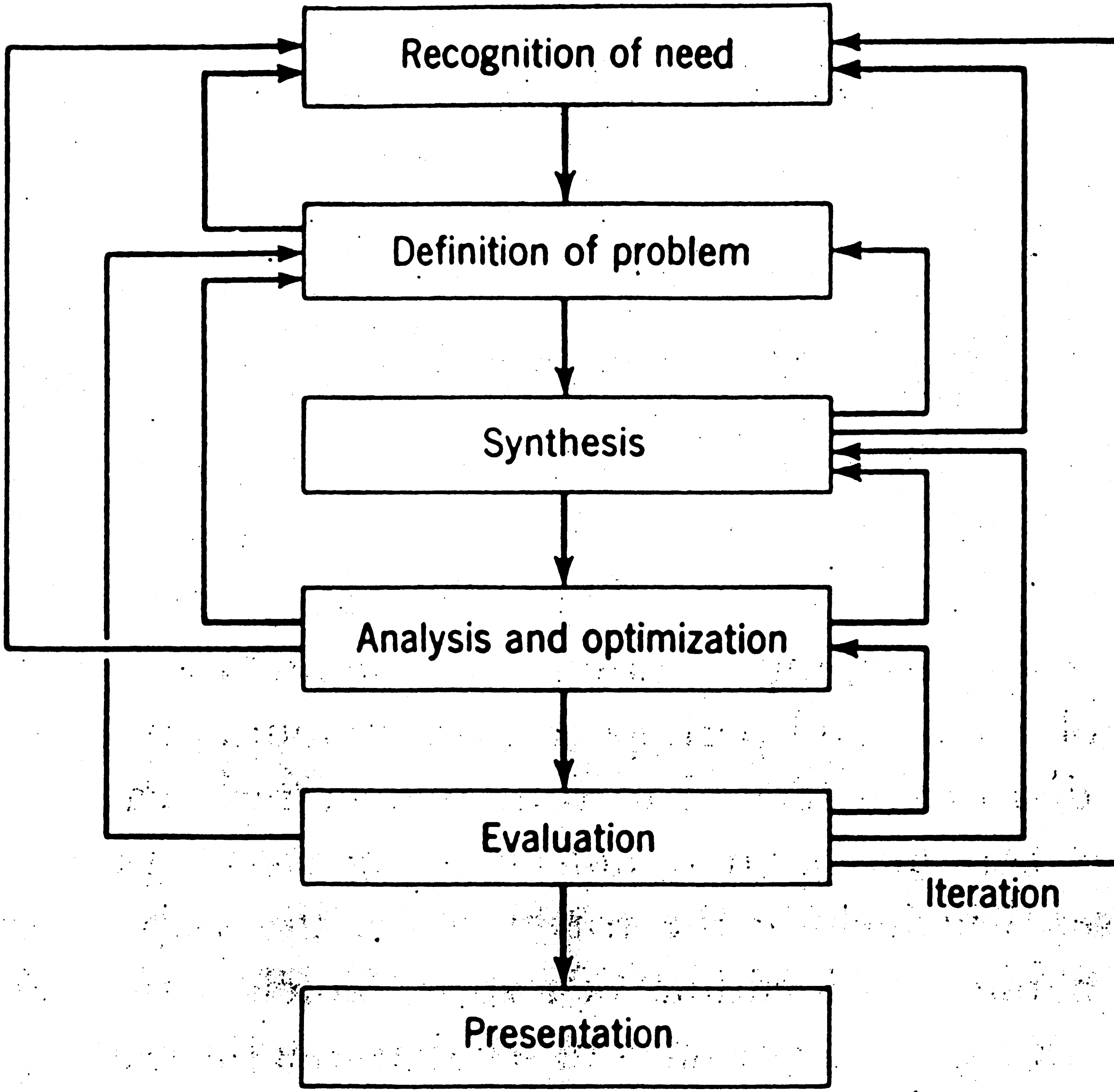
1-3 THE PHASES OF DESIGN



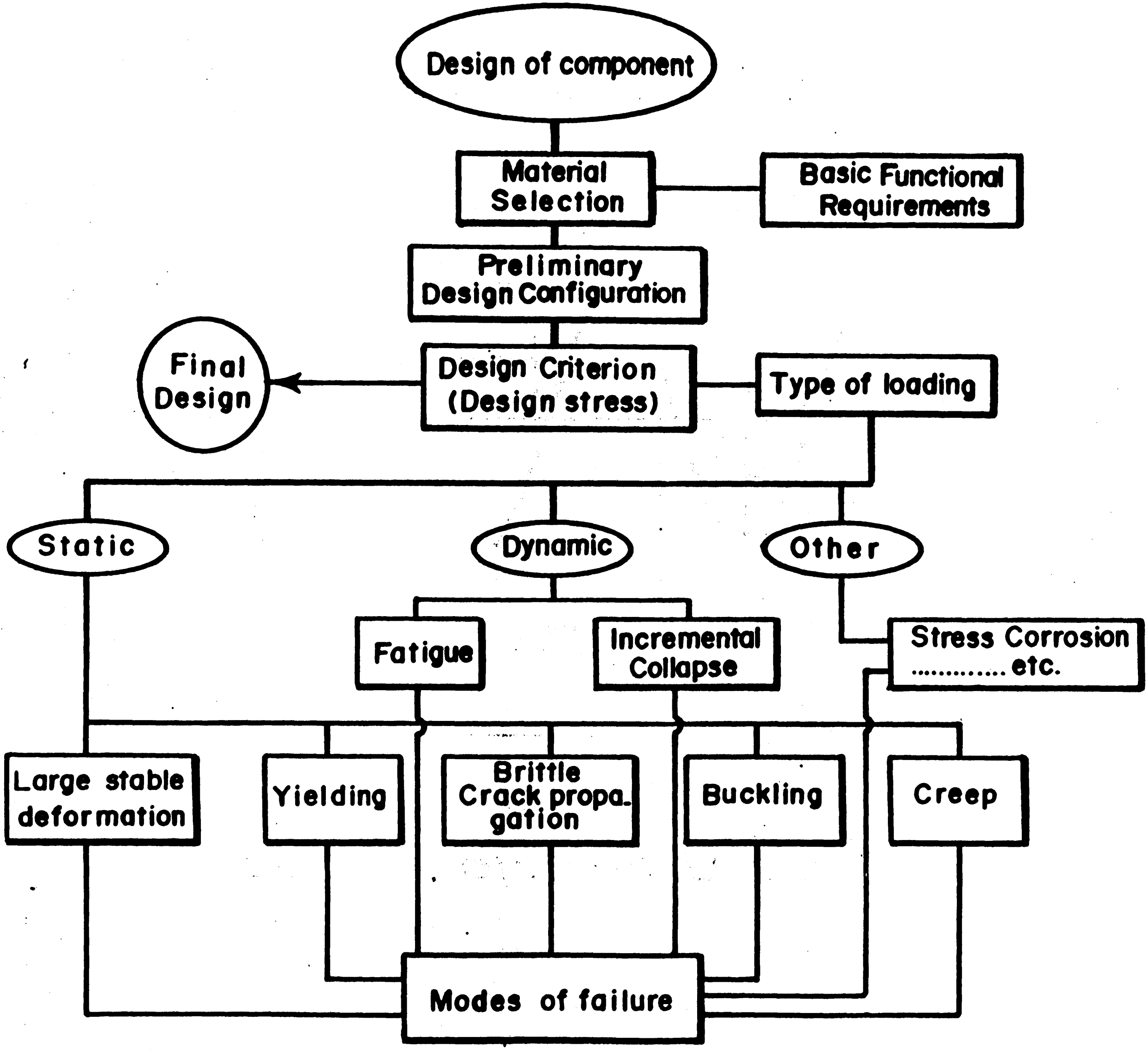
CODES AND STANDARDS

Aluminum Association (AA)
American Gear Manufacturers Association (AGMA)
American Institute of Steel Construction (AISC)
American Iron and Steel Institute (AISI)
American National Standards Institute (ANSI)*
American Society of Mechanical Engineers (ASME)
American Society for Metals (ASM)
American Society of Testing and Materials (ASTM)
American Welding Society (AWS)
Anti-Friction Bearing Manufacturers Association (**AFBMA**)
British Standards Institution (BSI)
Industrial Fasteners Institute (IFI)
Institution of Mechanical Engineers (I. Mech. E.)
International Bureau of Weights and Measures (BIPM)
International Standards Organization (ISO)
National Bureau of Standards (NBS)
Society of Automotive Engineers (SAE)

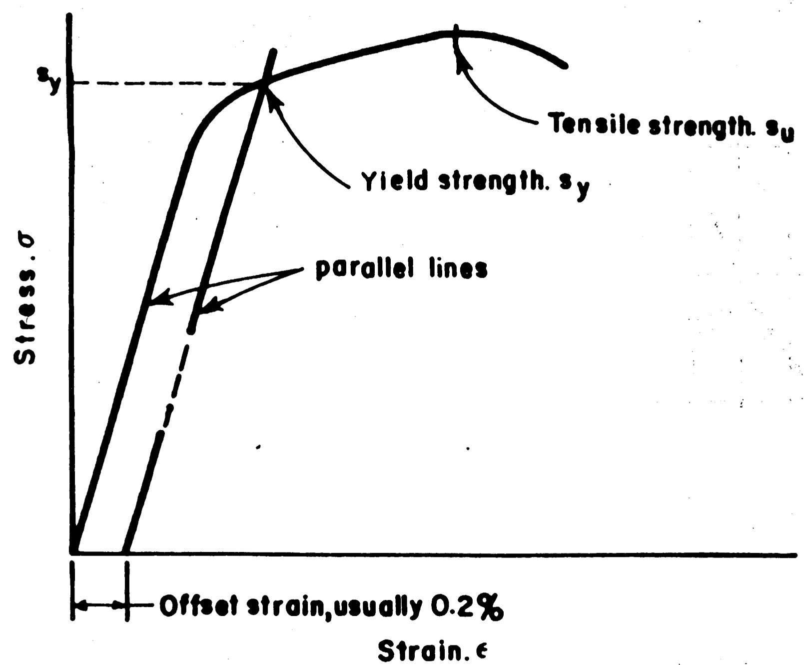
1-6 DESIGN CONSIDERATIONS

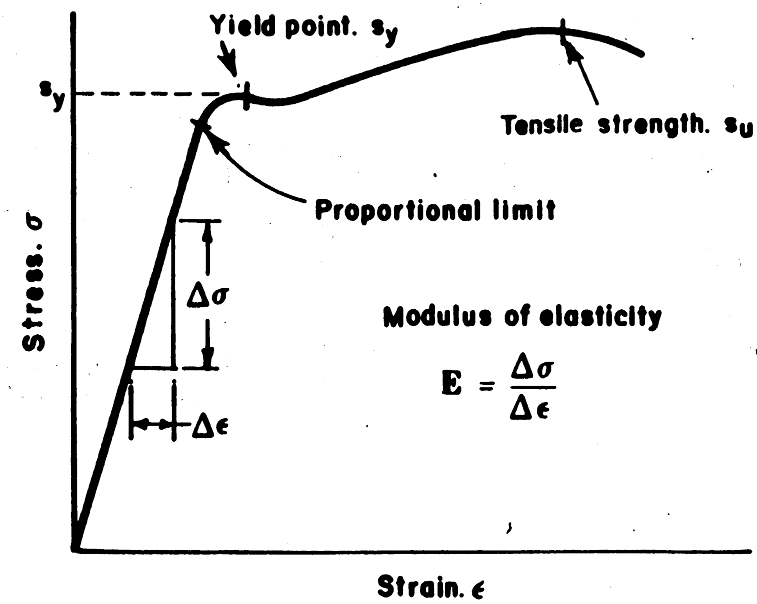
1 Strength
2 Reliability
3 Thermal considerations
4 Corrosion
5 Wear
6 Friction
7 Processing
8 Utility
9 Cost
10 Safety
11 Weight
12 Noise
13 Styling
14 Shape
15 Size
16 Flexibility
17 Control
18 Stiffness
19 Surface finish
20 Lubrication
21 Maintenance
22 Volume

DESIGN AND FAILURE MODES

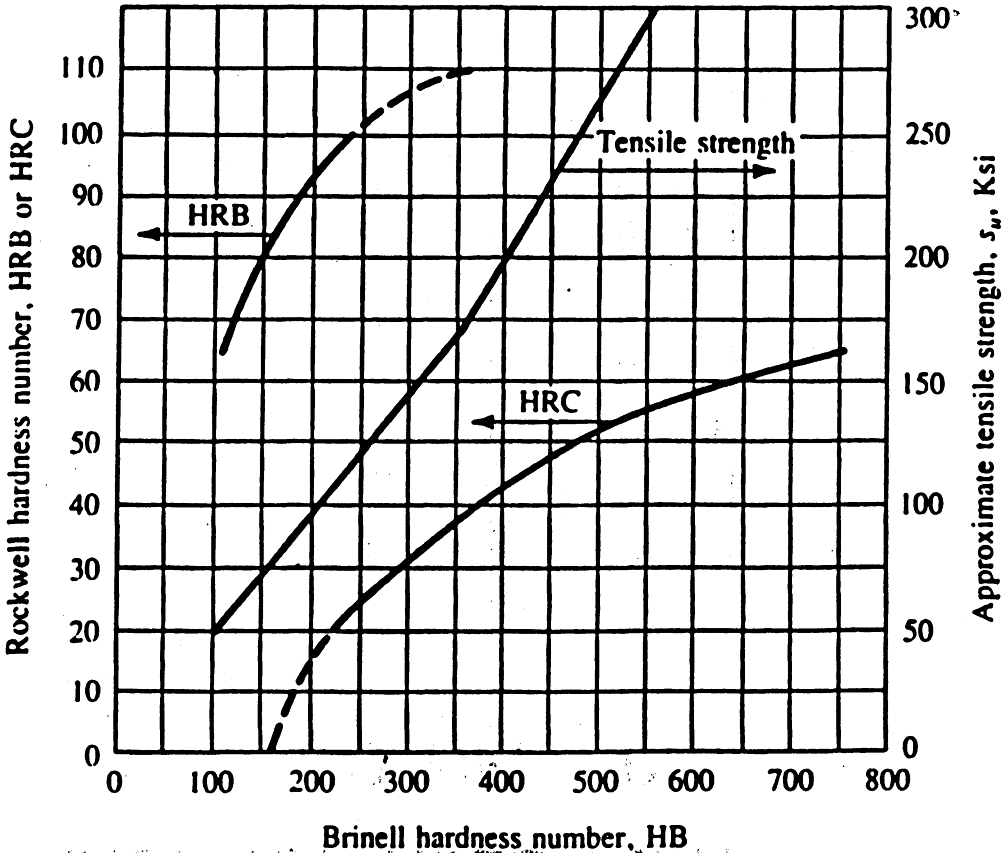


TYPICAL STRESS-STRAIN DIAGRAMS FOR MATERIALS SHOWING A DISTINCT YIELD POINT (STEELS) AND MATERIALS HAVING NO YIELD POINT (ALUMINUM)





HARDNESS CONVERSION



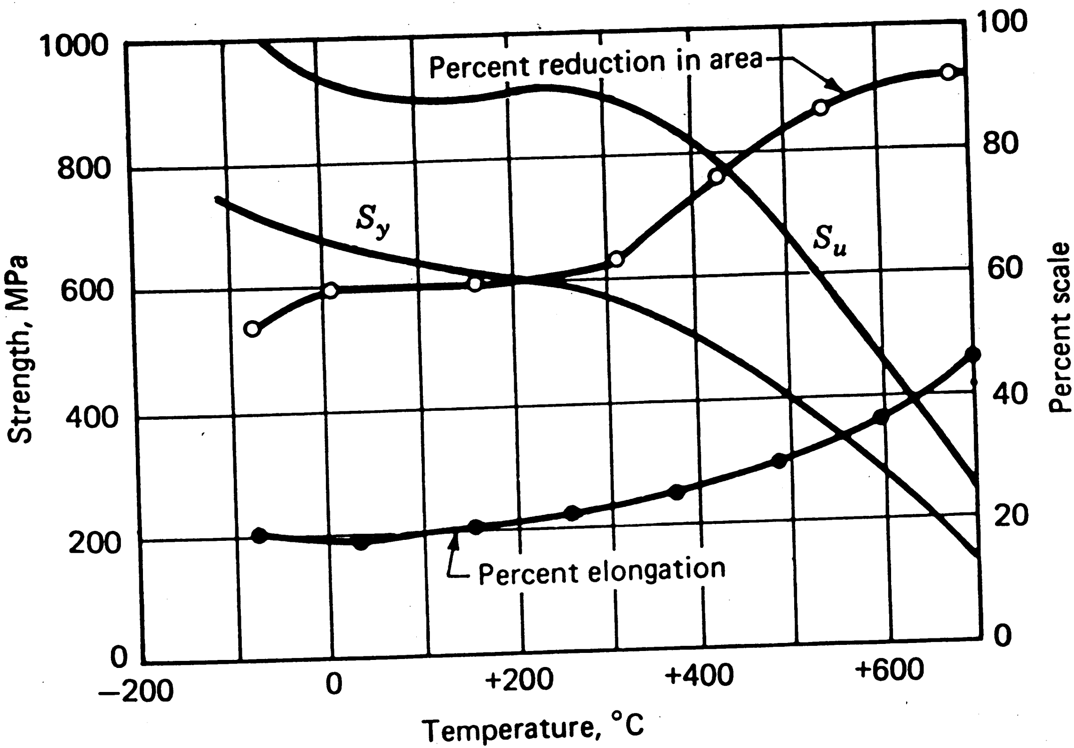


FIGURE 4-9 The effect of temperature on tensile properties of steel.

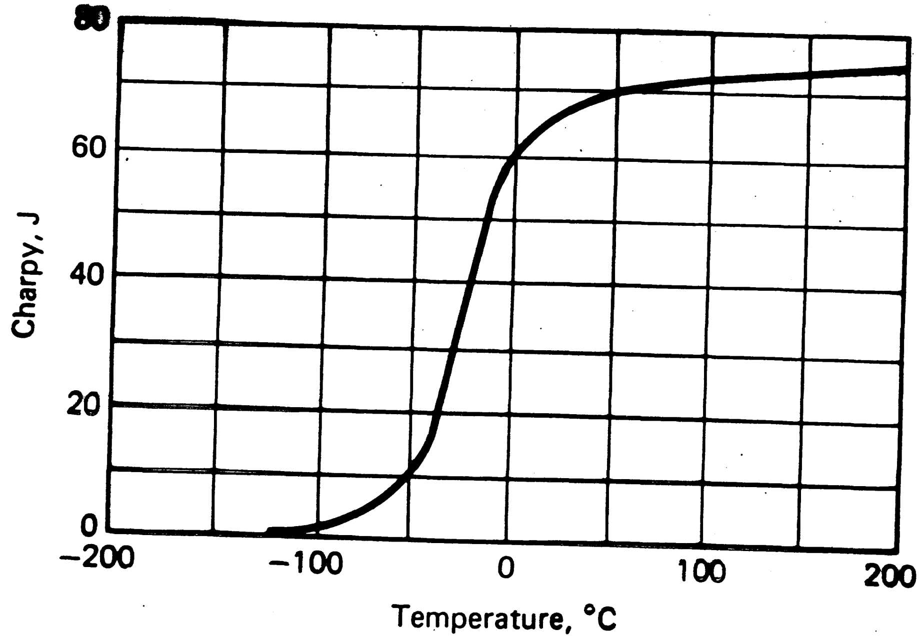


FIGURE 4-7 The effect of temperature on impact

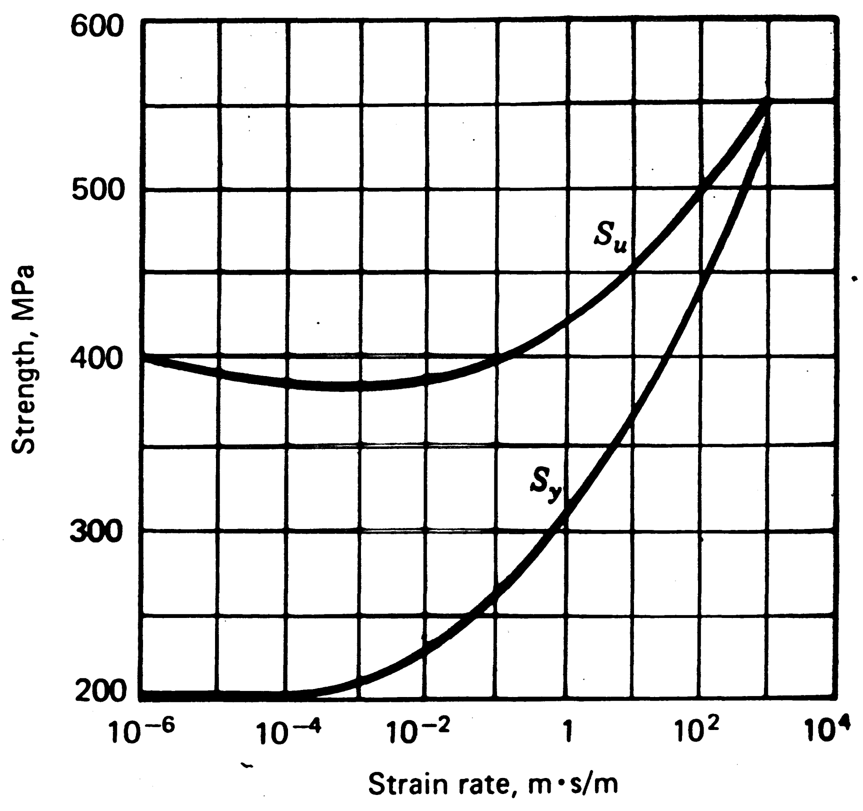


FIGURE 4-8 Influence of strain rate on tensile properties.

STEEL DESIGNATION SYSTEM

General Form of Designation

AISI x x xx

- xx — Carbon content
- x (second) — Specific alloy in the group
- x (first) — Alloy group: indicates major alloying elements

Examples

AISI 1 0 20

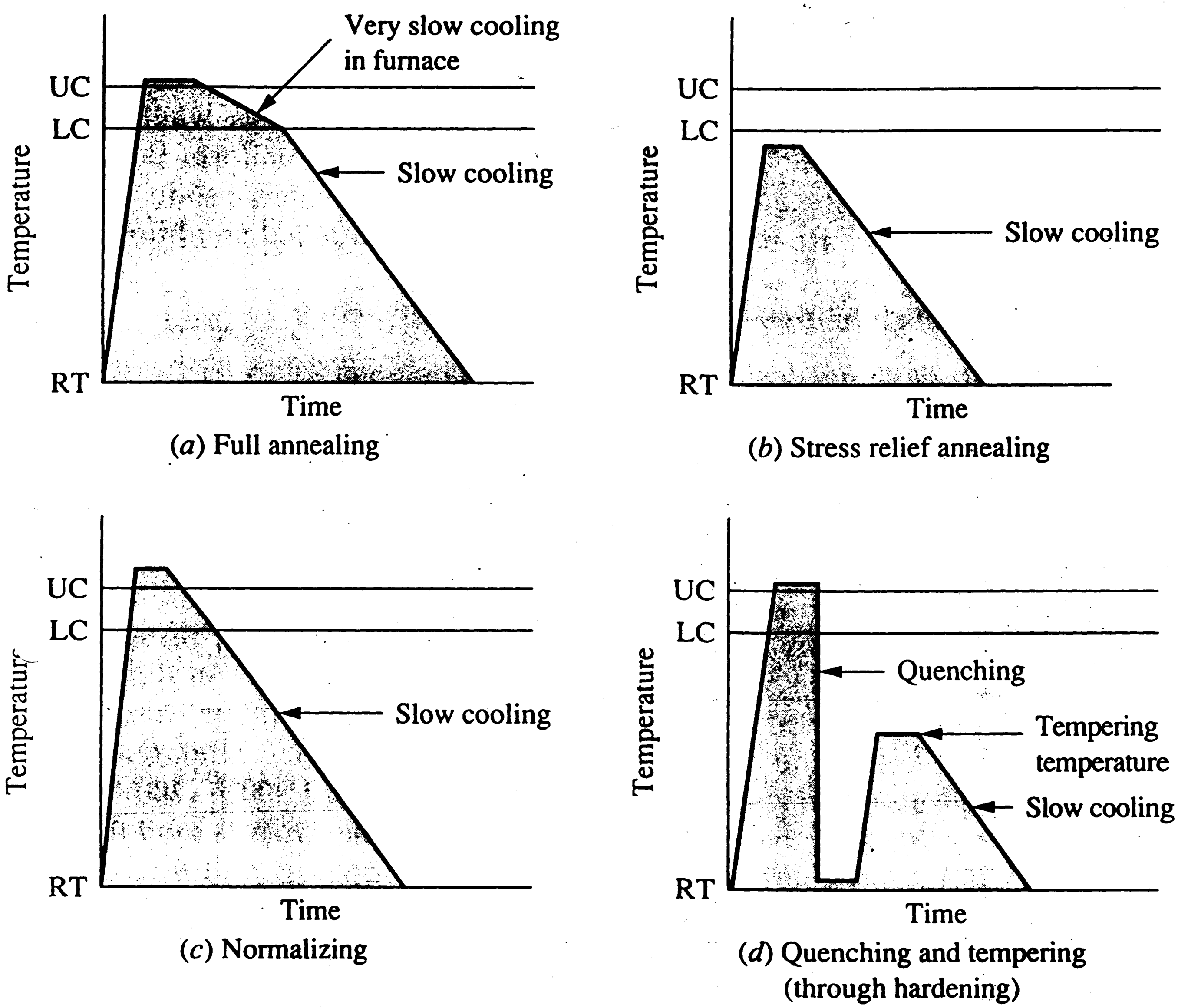
- 20 — 0.20 % Carbon
- 0 — No other major alloying element besides carbon
- 1 — Carbon steel

AISI 4 3 40

- 40 — 0.40 % Carbon
- 3 — Nickel and chromium added in specified concentrations
- 4 — Molybdenum alloy steel

ALLOY GROUPS IN THE AISI NUMBERING SYSTEM

10xx	Plain carbon steel: No significant alloying element except carbon and manganese; less than 1.0 percent manganese. Also called *nonresulfurized*.
11xx	Free cutting steel: Resulfurized. Sulfur content (typically 0.10 percent) improves machinability.
12xx	Free cutting steel: Resulfurized and rephosphorized. Presence of increased sulfur and phosphorus improves machinability and surface finish.
12Lxx	Free cutting steel: Lead added to 12xx steel further improves machinability.
13xx	Manganese steel: Nonresulfurized. Presence of approximately 1.75 percent manganese increases hardenability.
15xx	Carbon steel: Nonresulfurized; greater than 1.0 percent manganese.
23xx	Nickel steel: Nominally 3.5 percent nickel.
25xx	Nickel steel: Nominally 5.0 percent nickel.
31xx	Nickel-chromium steel: Nominally 1.25 percent Ni, 0.65 percent Cr.
33xx	Nickel-chromium steel: Nominally 3.5 percent Ni, 1.5 percent Cr.
40xx	Molybdenum steel: 0.25 percent Mo.
41xx	Chromium-molybdenum steel: 0.95 percent Cr, 0.2 percent Mo.
43xx	Nickel-chromium-molybdenum steel: 1.8 percent Ni; 0.5 percent or 0.8 percent Cr; 0.25 percent Mo.
44xx	Molybdenum steel: 0.5 percent Mo.
46xx	Nickel-molybdenum steel: 1.8 percent Ni, 0.25 percent Mo.
48xx	Nickel-molybdenum steel: 3.5 percent Ni, 0.25 percent Mo.
5xxx	Chromium steel: 0.4 percent Cr.
51xx	Chromium steel: Nominally 0.8 percent Cr.
51100	Chromium steel: Nominally 1.0 percent Cr; bearing steel, 1.0 percent C.
52100	Chromium steel: Nominally 1.45 percent Cr; bearing steel, 1.0 percent C.
61xx	Chromium-vanadium steel: 0.50–1.10 percent Cr, 0.15 percent V.
86xx	Nickel-chromium-molybdenum steel: 0.55 percent Ni, 0.5 percent Cr, 0.20 percent Mo.
87xx	Nickel-chromium-molybdenum steel: 0.55 percent Ni, 0.5 percent Cr, 0.25 percent Mo.
92xx	Silicon steel: 2.0 percent silicon.
93xx	Nickel-chromium-molybdenum steel: 3.25 percent Ni, 1.2 percent Cr, 0.12 percent Mo.



Note:
RT = room temperature
LC = lower critical temperature
UC = upper critical temperature

Figure 2–7 Heat Treatments for Steel

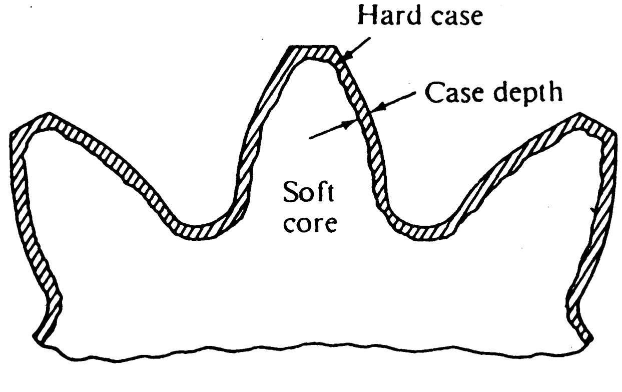


Figure 2–8 Typical Case Hardened Gear-Tooth Section

Table 2–7 Comparison of Specific Strength and Specific Modulus for Selected Materials

Material	*Tensile Strength, s_u (Ksi)*	*Specific Weight, γ (lb/in^3)*	*Specific Strength (in)*	*Specific Modulus (in)*
Steel ($E = 30 \times 10^6$ psi)				
AISI 1020 HR	55	0.283	0.194×10^6	1.06×10^8
AISI 5160 OQT 700	263	0.283	0.929×10^6	1.06×10^8
Aluminum ($E = 10.0 \times 10^6$ psi)				
6061-T6	45	0.098	0.459×10^6	1.02×10^8
7075-T6	83	0.101	0.822×10^6	0.99×10^8
Titanium ($E = 16.5 \times 10^6$ psi)				
Ti-6Al-4V	160	0.160	1.00×10^6	1.03×10^8
Quenched and aged at 1 000°F				
Graphite/Epoxy Composite ($E = 19.7 \times 10^6$ psi)				
62% fiber content	278	0.057	4.86×10^6	3.45×10^8
Boron/Epoxy Composite ($E = 30.0 \times 10^6$ psi)				
60% fiber content	270	0.075	3.60×10^6	4.00×10^8
Aramid/Epoxy Composite ($E = 11.0 \times 10^6$ psi)				
60% fiber content	200	0.050	4.0×10^6	2.20×10^8
Glass/Epoxy Composite ($E = 4.0 \times 10^6$ psi)				
34% fiber content	114	0.061	1.87×10^6	0.66×10^8

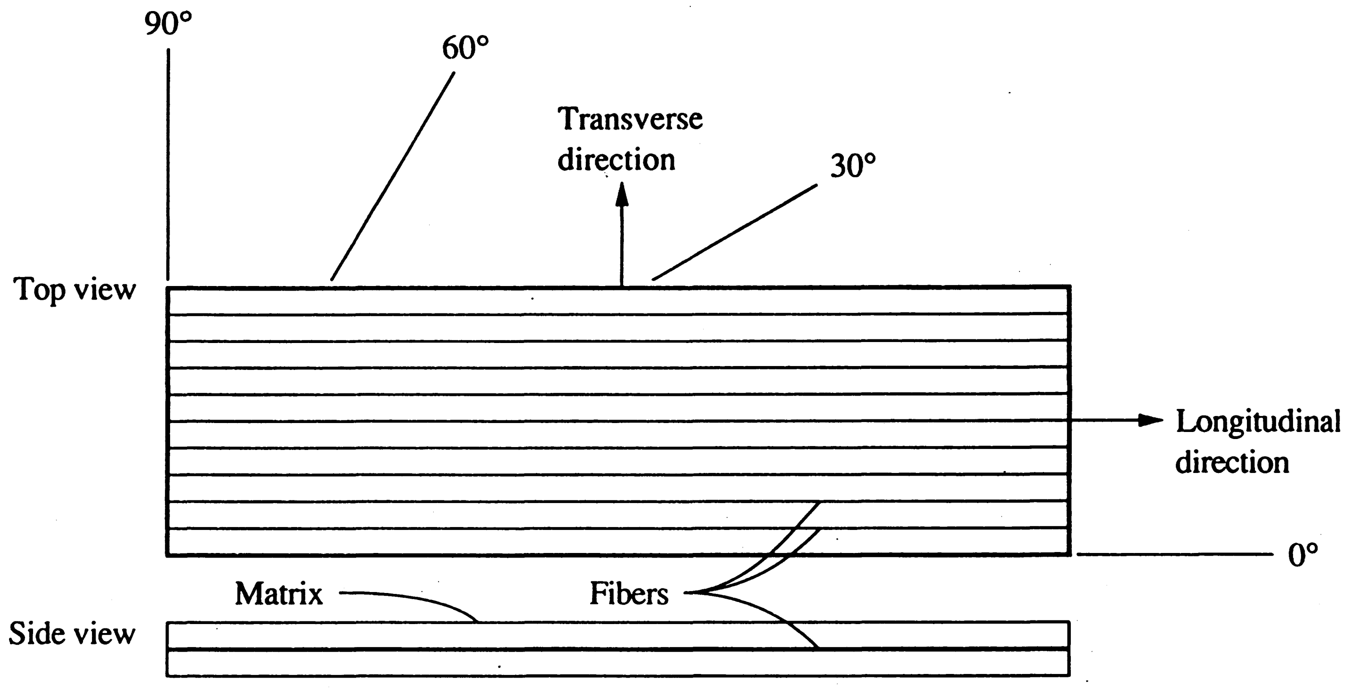


Figure 2–11 Notation for Directions in a Single-layer Composite Material with Continuous Fibers

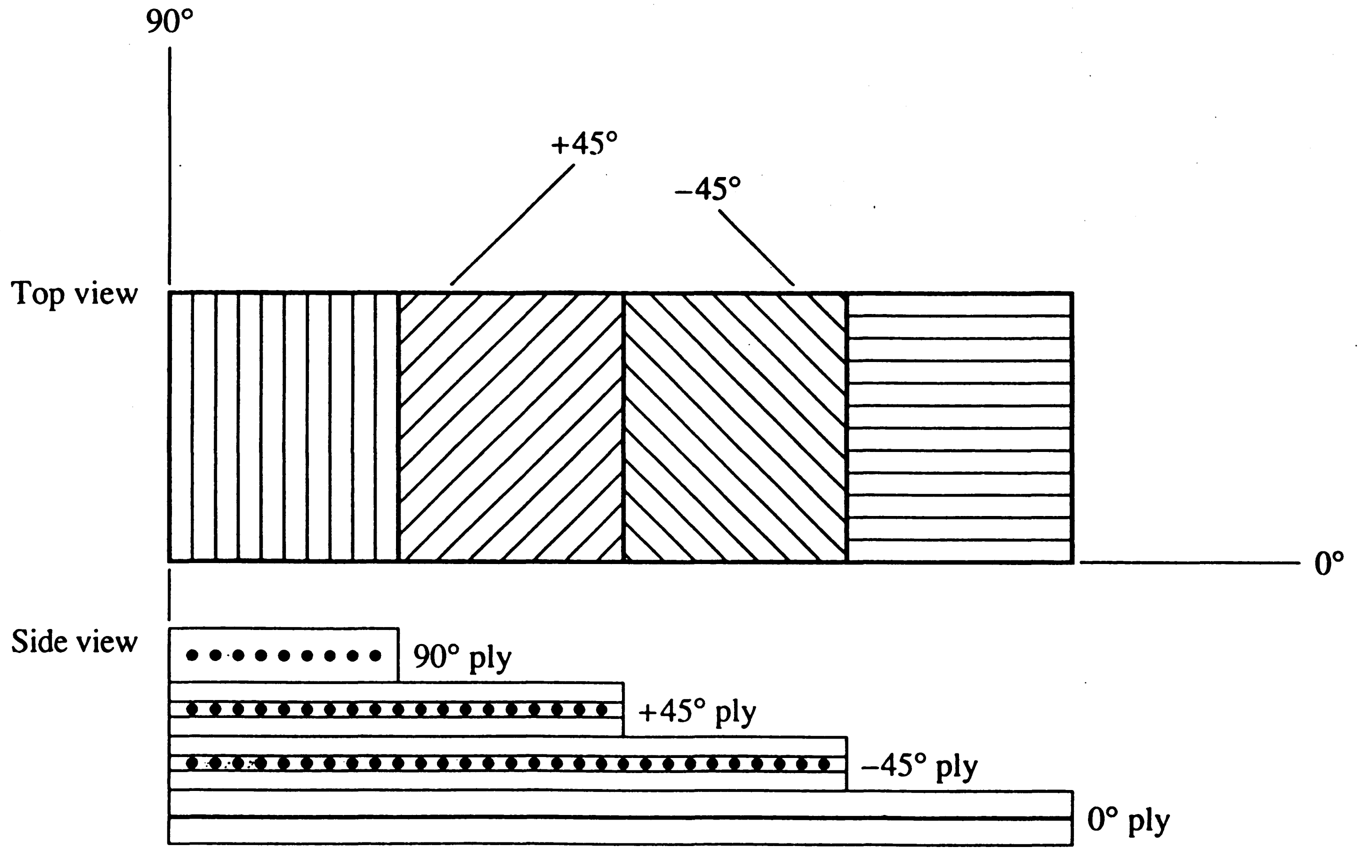


Figure 2–12 Laminated Composite with Four Layers Having a Lay-up Pattern: [90/+45/−45/0]

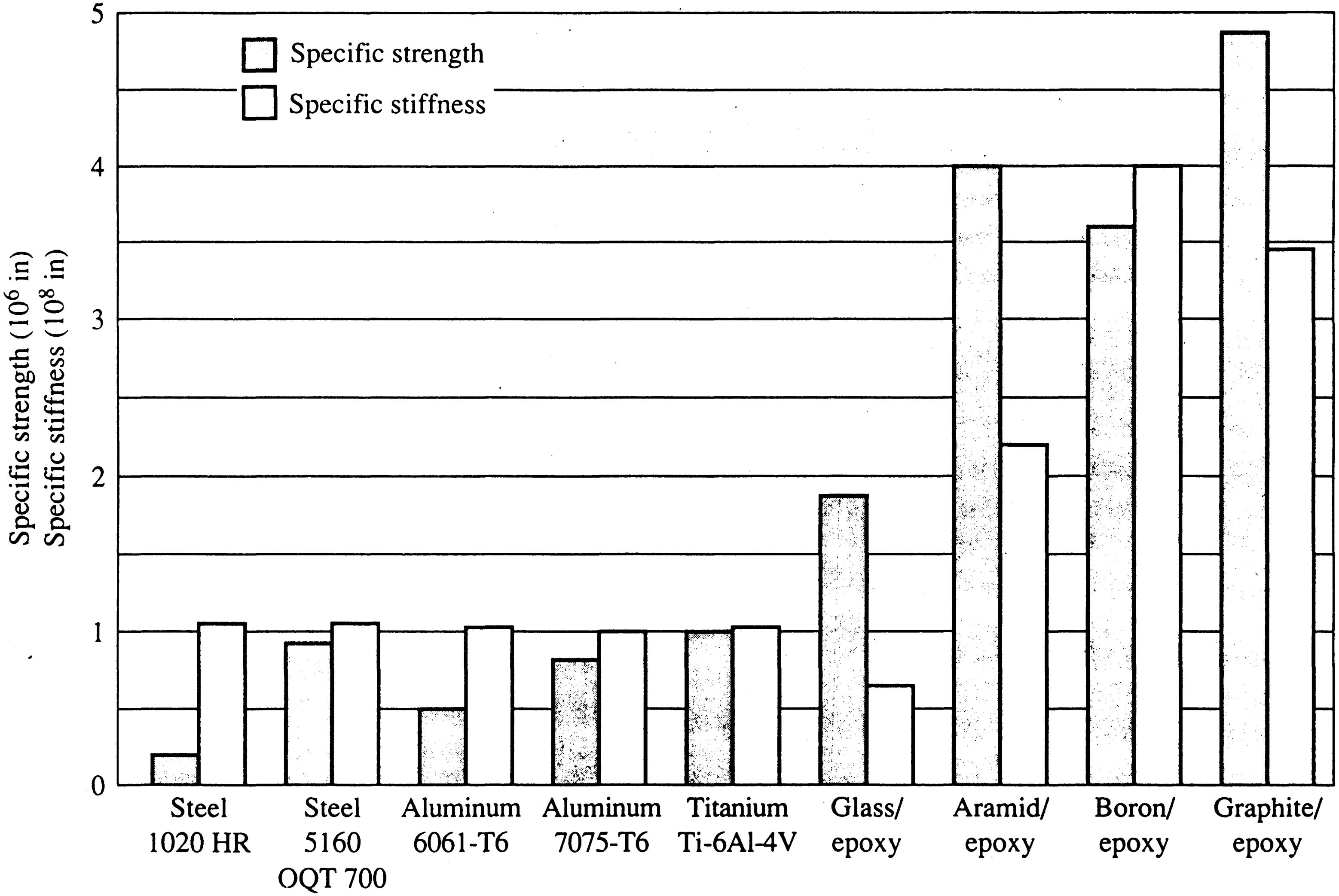
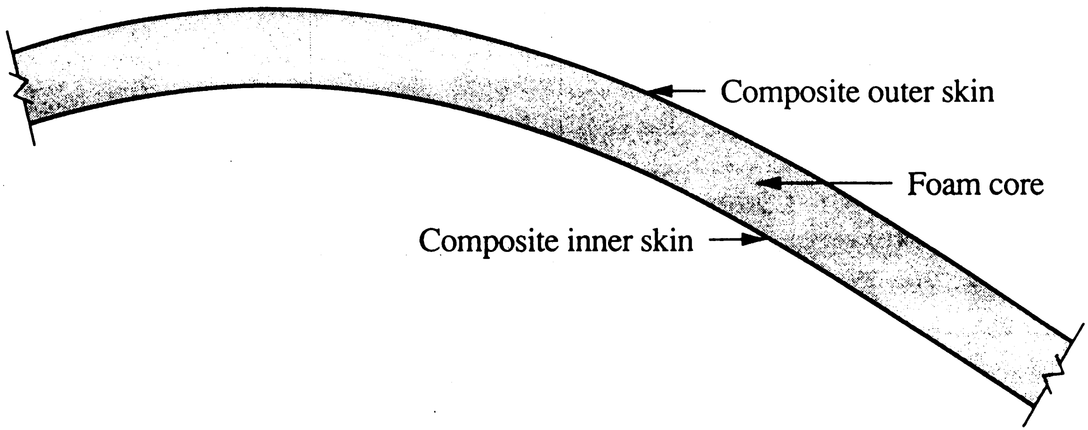
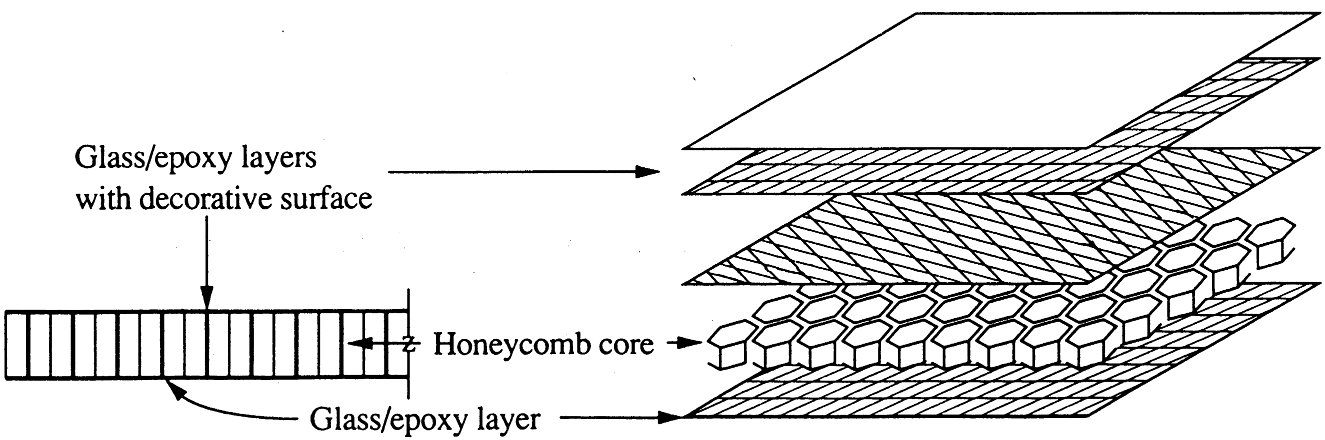


Figure 2–10 Comparison of Specific Strength and Specific Stiffness for Selected Materials



(*a*) Curved panel with foam core and composite skins



(*b*) Flat panel with honeycomb core and composite skins

Figure 2–13 Laminated Panels with Lightweight Cores

INTERNAL REACTION COMPONENTS

F_x = N = Normal force

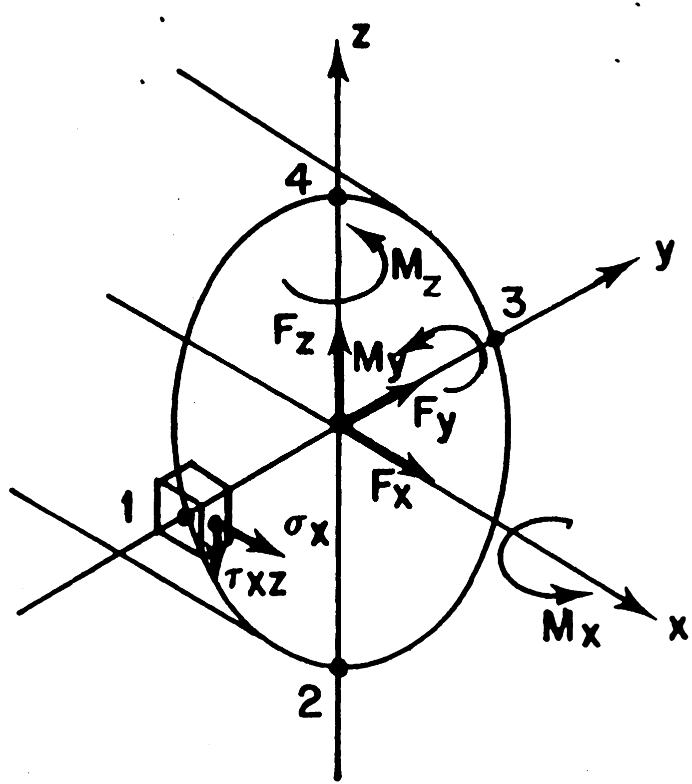
F_y = V_y = Shearing force

F_z = V_z = Shearing force

M_x = M_t = T = Twisting moment

M_y = Bending moment

M_z = Bending moment



STRESSES DUE TO THE SIX INTERNAL REACTION COMPONENTS

INTERNAL REACTION COMPONENT	STRESS DISTRIBUTION EQUATION	MAXIMUM STRESS FOR A CIRCULAR SEC.	LOCATION OF MA STRESS
Normal force N	$\sigma_x = \frac{N}{A}$	$\sigma_x = \frac{N}{A}$	Uniform over sectio
Shearing force V_y	$\tau_{xy} = \frac{V_y Q_z}{I_z t_z}$	$\tau_{xy} = \frac{4}{3} \frac{V_y}{A}$	Along the z-axis (line 2-4)
Shearing force V_z	$\tau_{xz} = \frac{V_z Q_y}{I_y t_y}$	$\tau_{xz} = \frac{4}{3} \frac{V_z}{A}$	Along the y-axis (line 1-3)
Twisting Moment T (for a circular cross-section)	$\tau = \frac{T \rho}{\frac{\pi}{32} d^4}$	$\tau_{max} = \frac{16T}{\pi d^3}$	Outermost circumference
Bending Moment M_y (for a circular cross-section)	$\sigma_x = \frac{-M_y Z}{I_y}$ $\sigma_x = \frac{-M_y Z}{\frac{\pi}{64} d^4}$	$\sigma_x = \frac{-M_y Z_{max}}{I_y}$ $\sigma_x = \frac{32 M_y}{\pi d^3}$	Points 2 & 4
Bending Moment M_z (for a circular cross sections)	$\sigma_x = \frac{-M_z y}{I_z}$ $\sigma_x = \frac{-M_z y}{\frac{\pi}{64} d^4}$	$\sigma_x = \frac{M_z y_{max}}{I_z}$ $\sigma_x = \frac{32 M_z}{\pi d^3}$	Points 1 & 3