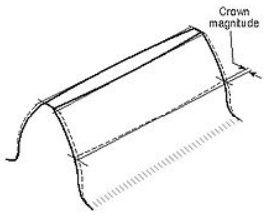
- A shaft is a rotating member usually of circular cross section (solid or hollow) used to transmit power
  - Gears, pulleys and flywheels are mounted on the shaft and the shaft is supported by bearings
  - Is subjected to bending in both planes, thrust loads and torque
  - Loading can be fully reversed or repeated
- An axle is a non rotating member which is used to support rotating wheels

Design considerations

- Yielding
- Fatigue failure
- Excessive deflection and slope beyond allowable limits
- Dynamic stability during operation
- Provide appropriate interfaces for locating and securing elements like gears, pulleys etc.
- The location of these elements are governed by overall layout of the system in which shaft is a part
- Assembly and dis-assembly considerations

Slopes

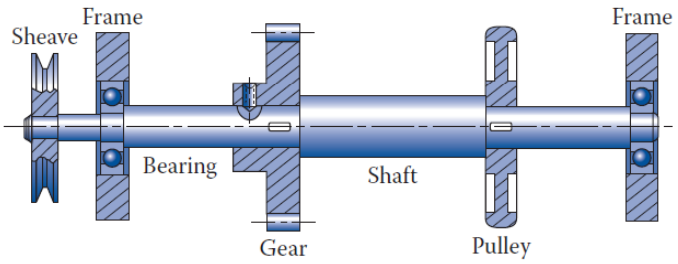
Tapered roller	0.0005–0.0012 rad
Cylindrical roller	0.0008–0.0012 rad
Deep-groove ball	0.001–0.003 rad
Spherical ball	0.026–0.052 rad
Self-align ball	0.026–0.052 rad
Uncrowned spur gear	< 0.0005 rad

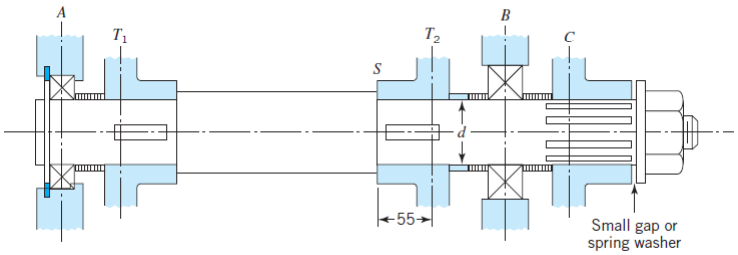


Transverse deflections

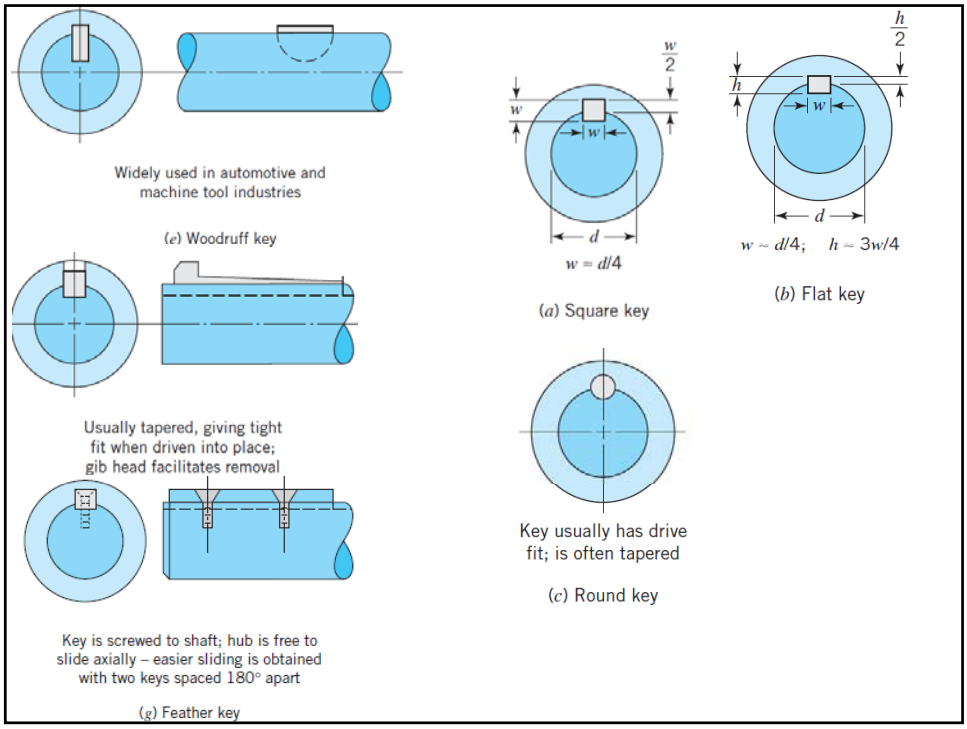
Spur gears with $P < 10$ teeth/in	0.010 in 0.25 mm
Spur gears with $11 < P < 19$	0.005 in 0.125 mm
Spur gears with $20 < P < 50$	0.003 in 0.076 mm

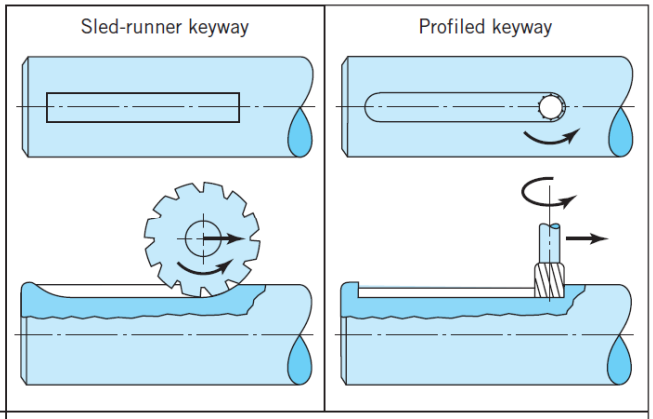
- Shaft layout: Designing the geometric configuration of the shaft for positioning and securing gears, pulleys etc.



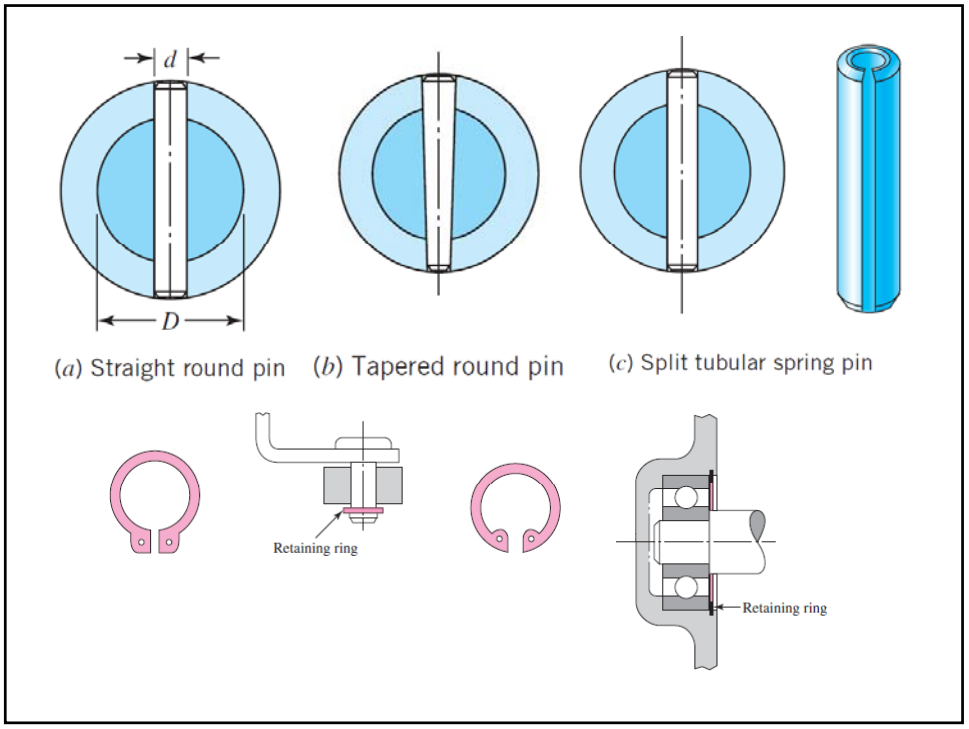


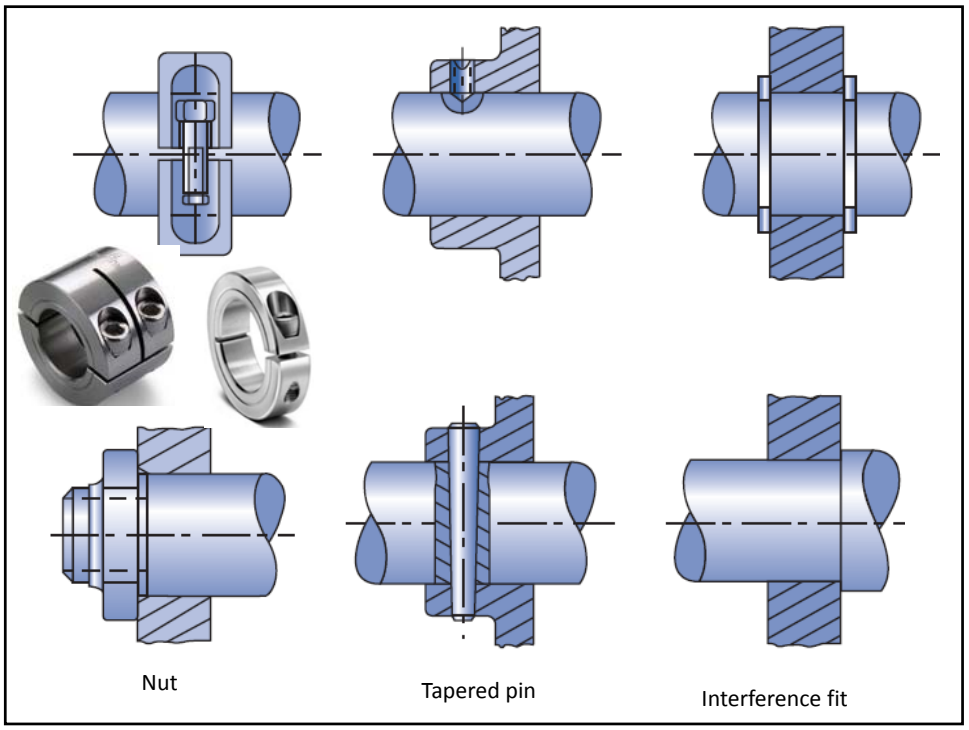
(c) Shaft layout





Steel	Fatigue stress concentration factor, K_f			
	Bending	Torsion	Bending	Torsion
Annealed (less than 200 Bhn)	1.3	1.3	1.6	1.3
Quenched and drawn (over 200 Bhn)	1.6	1.6	2.0	1.6


d
D
(a) Straight round pin
(b) Tapered round pin
(c) Split tubular spring pin
Retaining ring
Retaining ring


Nut
Tapered pin
Interference fit

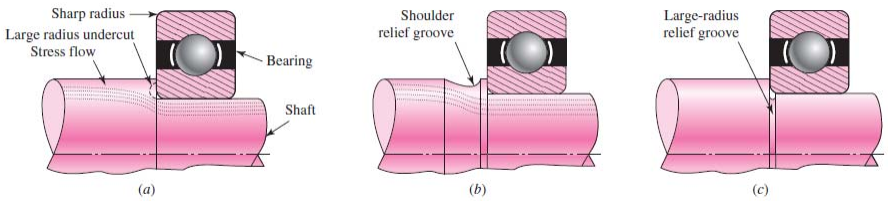


Figure 7–9

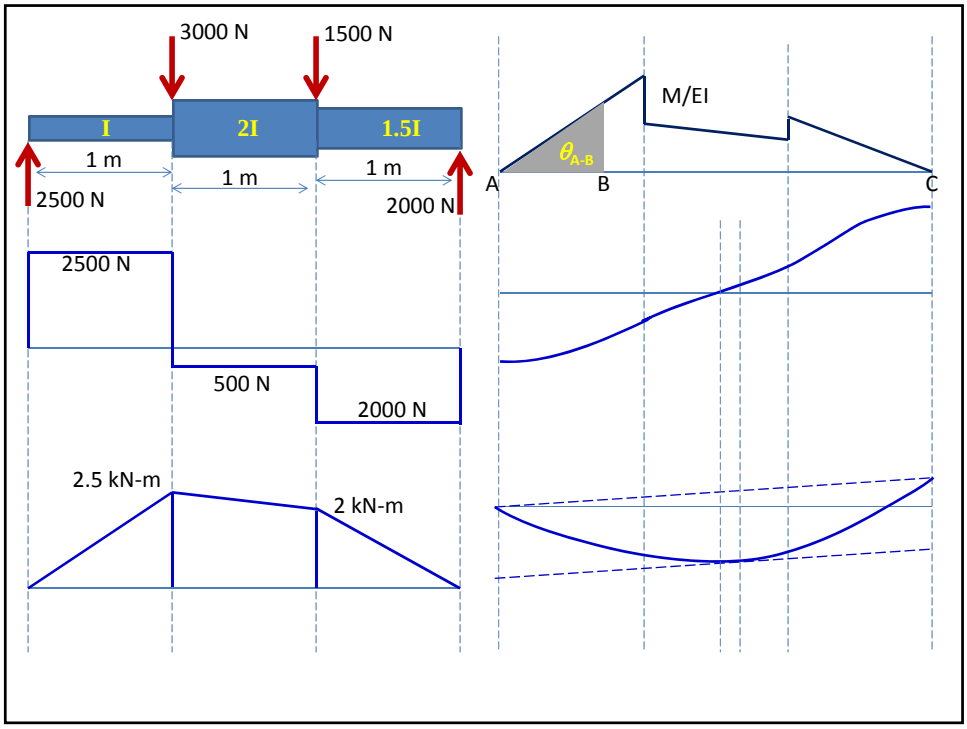
Techniques for reducing stress concentration at a shoulder supporting a bearing with a sharp radius. (*a*) Large radius undercut into the shoulder. (*b*) Large radius relief groove into the back of the shoulder. (*c*) Large radius relief groove into the small diameter

	Bending	Torsional	Axial
Shoulder fillet—sharp ($r/d = 0.02$)	2.7	2.2	3.0
Shoulder fillet—well rounded ($r/d = 0.1$)	1.7	1.5	1.9
End-mill keyseat ($r/d = 0.02$)	2.2	3.0	—
Sled runner keyseat	1.7	—	—
Retaining ring groove	5.0	3.0	5.0

Missing values in the table are not readily available.

Shaft deflection

- Complete geometry and dimensions along with support conditions are needed
- Deflection calculation is usually performed after design for yield and fatigue
- Both linear deflection and slope have to be obtained
- Shaft bends in two planes invariably
- Diameter can vary along the shaft length
- Options
  - A 3D finite element analysis can be carried out
  - Separate 2D analysis for bending in each plane based on MOM can be performed
  - The resultant deflection can be obtained by vector addition
- Fillets, key ways, grooves etc. do not affect the rigidity significantly and can be neglected


3000 N
1500 N
I
2I
1.5I
1 m
1 m
1 m
2500 N
2000 N
2500 N
500 N
2000 N
2.5 kN-m
2 kN-m
M/EI
θ_{A-B}
A
B
C