Design philosophy against fatigue failure

- Infinite life design
- Safe-life design
- Fail-safe design
- Damage-tolerant design

Infinite-life design

- Stresses are some fraction of the fraction limit
- Oldest fatigue design philosophy
- This design is valid for the parts which are subjected to vary large number of cycles of uniform stress

Safe-life design

- Based on the assumption that the part is initially flaw-free and has a finite life.
- Fatigue life at a constant stress is subject to large amounts of statistical scatter.
- E.g., Air Force aircrafts are used a safe-life of ¼ of the life.
- The factor of 4 is used to account for environmental effects, materials property variations.
- Safe-life design is also used in pressure vessel and jet engine design.

Fail-safe design

- Fatigue cracks will not lead to failure before they can be detected and repaired.
- This design philosophy is developed in aircraft industry, where weight penalty of using large safety factors could not be tolerated.
- Fail-safe designs employ multiple load paths and crack stoppers built into the structure
- Criteria for inspection and detection of crack are done periodically.

Damage-tolerant design

- This is the latest design philosophy.
- This is extension of fail-safe design philosphy.
- Fatigue cracks will exist in an engineering structure.
- Fracture mechanics concepts are used to determine whether the crack will grow large enough to cause failure.
- Materials with high fracture toughness and slow crack growth are used.
- Indentifying critical damage areas through nondestructive evaluation (NDE) determines success of the design approach.

Corrosion fatigue

- Simultaneous action of cyclic stress and chemical attack is known as corrosion fatigue.
- Corrosion attack without cyclic stress produces pits and notches on the surface which reduce fatigue strength
- When corrosion attack occurs simultaneously with fatigue loading, a significant reduction of fatigue properties is observed.
- Materials which show definite fatigue limit when tested in air, show no indication of a fatigue limit when tested in a corrosive environment.

- In corrosion environment fatigue limit depends on testing speed.
- Higher the testing speed, smaller the damage due to corrosion.
- Metals show reduction in fatigue life when tested in air than in partial vacuum. E.g. Cu

Minimizing corrosion-fatigue damage

- Choice of the material based on corrosion resistant properties rather than conventional fatigue properties
- Stainless steel, bronze or Be-Cu preferred over heat-treated steel
- Metallic or nonmetallic coatings – should not rupture from cyclic strain
- Zn and Cd coatings on steel; Al coatings on Alclad Al alloys are successful.
- Nitriding, shot-peening are used in certain conditions.

Fretting

- A surface damage phenomenon, results when two surface in contact slight periodic relative motion
- Related to wear than corrosion fatigue
- Relative velocities of two surfaces are low than that in wear.
- E.g., surface of a shaft with a press-fitted hub or bearing
- Combination of mechanical and chemical effects

Machine Design Approach: Example

A steel shaft is heat-treated to BHN200. The shaft has a major diameter of 38 mm and a small diameter of 25 mm. There is a 2.5 mm radius at the shoulder between the diameters. The shaft is subjected to completely reversed cycles of stress of pure bending. The fatigue limit for the steel measured on polished specimens of 5 mm diameter is 290 MPa. The shaft is manufactured by machining from bar stock. What is the best estimate of the fatigue limit of the shaft?

Ref: Mechanical Metallurgy, G.E. Dieter