Company Logo

K. N. Toosi University of Technology

Faculty of Materials Science and Engineering

Selection of Engineering Materials

Eighth Session
(Materials Selection Process- 6)

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Material Selection Based on Fatigue Resistance

- ✓ In many engineering applications, the behavior of materials is influenced by factors other than the properties of the material itself. A prominent example of this is when a structure is subjected to fatigue loading.
- ✓ In fatigue loading conditions, the surface quality, manufacturing method, and design of the component have a significant impact on fatigue resistance.

Material Selection Based on Fatigue Resistance

- ✓ In most cases, achieving desirable fatigue life, the role of the material of the component, especially when free from discontinuities, is of secondary importance.
- ✓ In a component that has welds, bolts, or rivets, the contribution of the crack initiation stage to fatigue life is minimal, and most of the component's fatigue life is spent in the second stage related to crack growth.

Material Selection Based on Fatigue Resistance

- ✓ Increasing the tensile strength of metallic materials usually leads to an improvement in their fatigue strength. However, on the other hand, stronger materials are more sensitive to notches and require the removal of coarse particles in the second phase and achieving a fine and uniform structure in them.

- ✓ Experience has shown that the rate of crack growth is more dependent on mechanical considerations of continuity rather than material properties.

Material Selection Based on Fatigue Resistance

✓ Sensitivity to notches of a material (q) is expressed as follows:

$$q = \frac{K_f - 1}{K_t - 1}$$

K_f: The ratio of fatigue strength without the presence of stress concentration to fatigue strength with stress concentration.

K_t: Stress concentration factor, which represents the intensity of the notch effect and is obtained from the ratio of maximum localized stress at the notch tip to average stress.

Material Selection Based on Fatigue Resistance

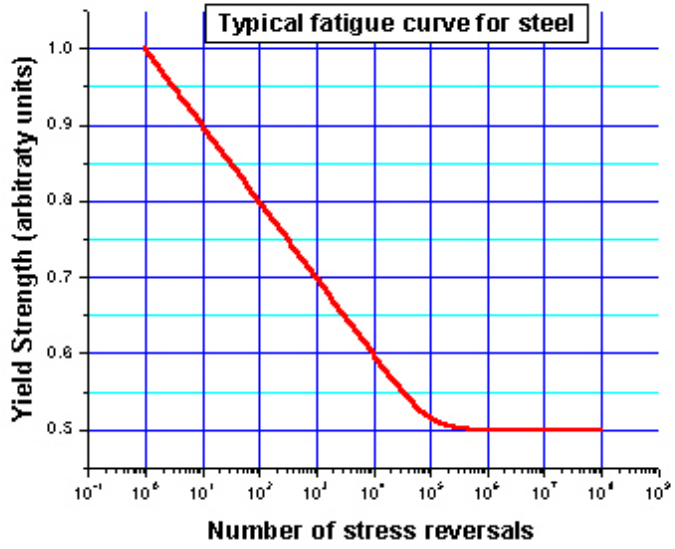
- ✓ The variable q can be considered as a criterion for the compatibility of K_t and K_f.
- ✓ By changing q from 0 to 1, the material becomes more sensitive to the presence of stress concentration.
- ✓ Generally, increasing the strength of materials makes them more sensitive to stress concentration points and increases q.
- ✓ The value of q depends on the size of the component and increases with its increase. Therefore, stress concentration points in larger components are more dangerous.

Material Selection Based on Fatigue Resistance

Steels

- ✓ Steels have the most applications in structures that are prone to fatigue, as they provide high fatigue strength and good manufacturability at relatively low production costs.

- ✓ Having a fatigue limit is one of the unique properties of steels that allows them to have a perpetual fatigue life at stresses below this limit.



Material Selection Based on Fatigue Resistance

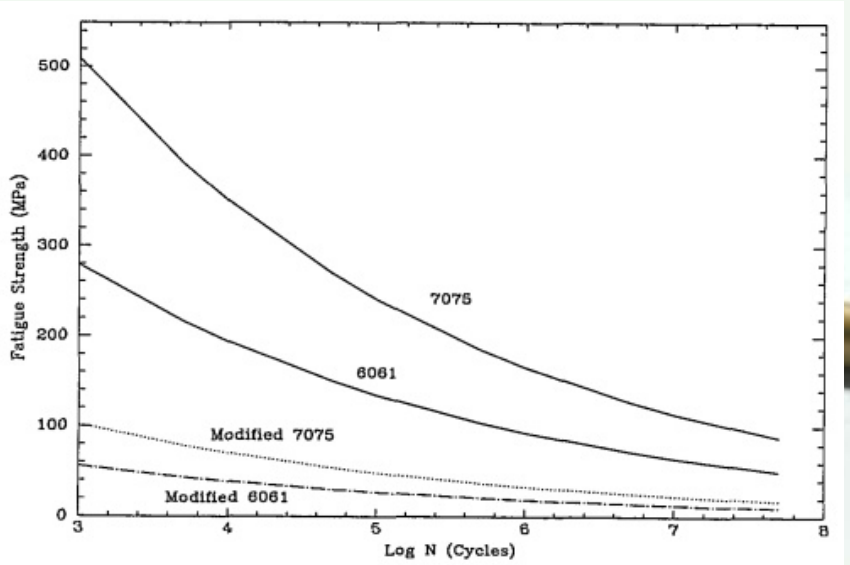
Steels

- ✓ The presence of inclusions in steels as internal discontinuities is very harmful, as they are prone to serve as sites for fatigue crack initiation.
- ✓ Therefore, the use of free-cutting steels in fatigue-resistant applications should be avoided. In cases where machinability is also necessary, the preference is to use leaded steels over steels containing phosphorus or sulfur because the spherical shape of lead particles in these steels reduces stress concentration compared to other angular and elongated inclusion shapes.

Material Selection Based on Fatigue Resistance

Non-Ferrous Alloys

- ✓ Non-ferrous alloys, except for titanium alloys, unlike steels, do not have a fatigue limit.
- ✓ In non-ferrous alloys, fatigue always occurs due to cyclic loads.
- ✓ Aluminum alloys combine corrosion resistance, lightweight, and adequate fatigue resistance.



Material Selection Based on Fatigue Resistance

Plastics

- ✓ The fatigue behavior of plastics is more complex than metals due to their viscoelastic properties. In addition to all factors affecting metal fatigue, the fatigue behavior of plastics depends on the type of loading, manufacturing process, and even the smallest changes in temperature and working environment.
- ✓ Due to low thermal conductivity, the residual heat in plastics can lead to their failure due to thermal fatigue or limit their performance to lower stresses.

Material Selection Based on Fatigue Resistance

Composites

- ✓ The failure mode in composite materials in fatigue is very complex and if there are internal stresses in them due to the difference in the contraction of the matrix and fibers, it strongly depends on the composite manufacturing process.
- ✓ Some fibers reinforced polymers have achieved better fatigue properties compared to metals. Today, due to their excellent fatigue properties, glass fibers reinforced epoxy composites are used as a substitute for steel in flat springs of some automobiles.

Material Selection Based on Fatigue Resistance

Composites

- ✓ Higher strength, better thermal conductivity, and less impact absorption are the reasons for the superiority of fatigue properties of crystalline polymers.
- ✓ The fatigue strength of fibers reinforced composites, like their static strength, depends on the direction of the fibers.
- ✓ The fatigue strength of unidirectional composite materials in directions other than the fibers direction is very minimal.

Material Selection Based on Wear Resistance

Effective Factors on the Wear Behavior of Materials:

1. Metallurgical variables such as hardness, toughness, chemical composition, and microstructure.
2. Operational variables include materials in contact, contact pressure, sliding speed, process temperature, surface quality, lubricant, and corrosion.

✓ Although the quality of materials in wear applications is generally influenced by their mechanical properties, but resistance to wear cannot always be attributed to a specific property.

Material Selection Based on Wear Resistance

- ✓ Generally, resistance to wear is not directly increased by tensile strength and hardness, but if other properties remain constant, hardness is a good criterion for comparing the resistance to wear of different materials.
- ✓ Wear is a surface phenomenon, so coatings and surface treatments play a very important role in controlling it.
- ✓ Surface coatings include materials resistant to wear.

Material Selection Based on Wear Resistance

- ✓ To avoid the need of making entire material wear-resistant, which are unnecessary and espensive, the following surface treatment is used:

1. Thermal surface treatments like flame heating or induction heating that harden the surface without affecting the core material.
2. Surface alloying such as carburizing, nitriding, and carbonitriding.

- ✓ Not all materials and components are suitable for surface treatments, and this treatment is destroyed by peeling.

Material Selection Based on Wear Resistance

Wear Resistance of Steels

- ✓ Although mild steels are very cheap and widely used, their wear resistance is weak and they undergo severe surface damage when sliding dry and without lubricant.
- ✓ Increasing the carbon content of steel has helped to improve its wear resistance, but it also increases the price.
- ✓ Among steels, low-alloy steels or surface-hardenable carbon steels are more wear-resistant types.

Material Selection Based on Wear Resistance

Wear Resistance of Steels

- ✓ If resistance to abrasion, corrosion, and high temperature is needed, precipitation hardening stainless steels can be chosen.
- ✓ Austenitic manganese steels can be used in cases where resistance to wear is important.

Material Selection Based on Wear Resistance

Wear Resistance of Steels

- ✓ Hadfield steels contain 0.7-1.45% C and 11-14% Mn and can also have elements like Cr, Mo, Ni, V, and Ti.
- ✓ Hadfield steels, compared to other types of wear-resistant steels, are not only more cost-effective but also have better toughness.
- ✓ Hadfield steels are resistant to metal-to-metal abrasion, such as in rails, and railway castings. These steels are highly suitable for conveyor belts and chains that are exposed to abrasive wear and are used for heavy loads.

Material Selection Based on Wear Resistance

Wear Resistance of Cast Irons

- ✓ Gray cast iron exhibits good wear resistance after casting, making it suitable for applications such as sliding path of tool holder in the machine tools and similar components.
- ✓ By creating martensitic or pearlitic structures in white cast iron, high wear resistance required for rollers and mill balls is achieved.
- ✓ In alloyed white cast iron, wear resistance is further improved, but it is more expensive.

Material Selection Based on Wear Resistance

Ceramics

- ✓ Ceramics can be used in various wear applications.
- ✓ The wear behavior of ceramics depends on the nature of the contacting surfaces and the presence of surface films.
- ✓ Generally, wear increases with increasing porosity and grain size in ceramics.
- ✓ The presence of surface layers such as water or oil can cause adhesion and wear.
- ✓ SiC are very suitable for making bearings and engine valve components.

Material Selection Based on Wear Resistance

Wear-Resistant Polymers

- ✓ Self-lubricating wear-resistant polymers compete with metals in many applications such as bearings and gears.
- ✓ In addition to ease of manufacture, better lubrication properties and ease of maintenance are other characteristics of polymers. These polymers are formulated with an internal lubricant agent.
- ✓ The simultaneous use of multiple lubricating agents creates optimal wear resistance.
- ✓ In polymers reinforced with carbon and aramid fibers, in addition to increasing strength, these types of fibers also improve wear resistance.

Material Selection Based on Wear Resistance

Wear-Resistant Polymers

✓ Despite the good advantages of polymers, the following limitations should also be considered when choosing wear-resistant polymers.

1. Polymer-on-polymer wear is much more severe than polymer-on-metal wear.
2. Sensitivity of wear resistance to slight temperature changes.
3. Sensitivity of polymers to surface roughness of metals in contact.
4. The type of metal has a significant impact on wear intensity. For example, replacing aluminum alloys with steel reduces the wear rate of plastics.