Creep-Fatigue Interaction

- Failure by fatigue can usually occur at any temperature below the melting point of a metal and still maintain the characteristics features of fatigue fractures, usually with little deformation, over the whole temperature range.

- At high temperatures, however, both the fatigue strength and the static strength of metal generally decrease as the operational temperature increases.

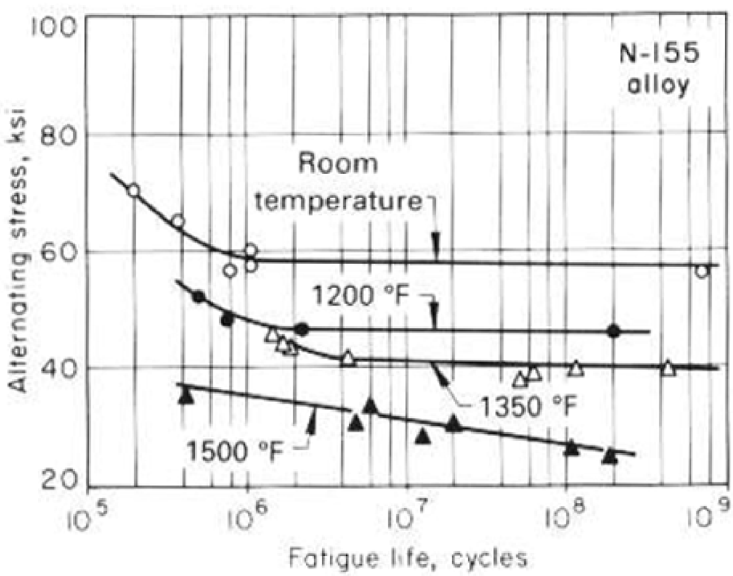

Fig. 1 Fatigue life of a specimen of N-155 alloy subjected to various temperatures and reversed bending stress

- Fig. 1 shows typical *S-N* curves for reversed bending fatigue tests conducted on a structural metal alloy at various temperatures. The fatigue limit is clearly lower at the higher temperatures.

- At high temperatures, application of a constant load to a metal component produces continuous deformation or creep, which will eventually lead to fracture if the load is maintained for a sufficient length of time.

- With increases in temperature stress rupture strength decreases rapidly to values that may be considerably lower than fatigue strength.

- Therefore, the primary requirement of a metal that will be subjected to high temperatures is that it has adequate stress-rupture strength.

- At room temperature, and except at very high frequencies, the frequency at which cyclic loads are applied has little effect on the fatigue strength of most metals.

- The effect, however, becomes much greater as the temperature increases and creep becomes more of a factor.

- At high temperatures, the fatigue strength often depends on the total time the stress is applied rather than solely on the number of cycles. This behavior occurs because of continuous deformation under load at high temperatures.

- Under fluctuating stress, the cyclic frequency affects both the fatigue life and the amount of creep.

- The principle method of studying creep-fatigue interactions has been to conduct strain controlled fatigue tests with variable frequencies with and without a holding period (hold time) during some portion of the test.

- The lower frequencies ($\leq 10^4$ cycles) and the hold times can allow creep to take place.

- In pure fatigue tests, at higher frequencies and short hold times, the fatigue mode dominates and failures start near the surface and propagate transgranularly.

- As the hold time is increased, or the frequency decreases, the creep component begins to play a role with increasing creep-fatigue interaction. In this region, fractures are of a mixed mode involving both fatigue cracking and creep cavitation.

- With prolonged hold times with occasional interspersed cycles, creep processes completely dominates and can be treated almost as pure cases of creep.

Thermal and Thermomechanical Fatigue

- Thermal fatigue failure is the result of temperature cycling (without external loading), as opposed to fatigue at high temperatures caused by strain cycling.

- Two conditions necessary for thermal fatigue are some form of mechanical constraint and a temperature change.

- Thermal expansion or contraction caused by a temperature change acting against a constraint causes thermal stress.

- Constraint may be external-for example, constraint imposed by rigid mountings for pipes-or it may be internal, in which case it is setup by a temperature gradient within the part.

- In thick sections, temperature gradients are likely to occur both along and through the material, causing highly triaxial stresses and reducing material ductility, even though the uniaxial ductility often increases with increasing temperature.

- Reduction in the ductility of the material gives rise to fractures that have a brittle appearance, often with many cleavage like facets in evidence.

- Thermomechanical fatigue involves simultaneous changes in temperature and mechanical strain.

- It differs from creep-fatigue in that the latter is carried out at constant nominal temperature (isothermal) conditions.

- As such, the deformation and fatigue damage due to thermomechanical fatigue cannot be predicted based on isothermal creep fatigue data.