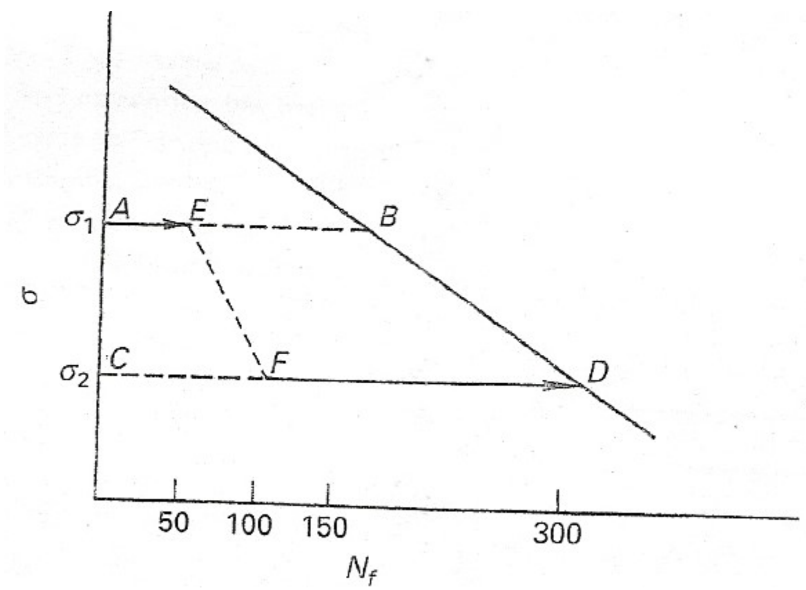
Cumulative damage and life exhaustion

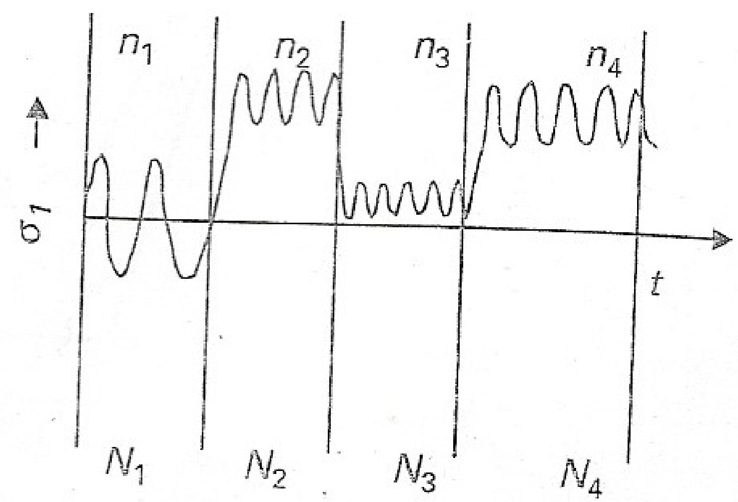
- Components in real life situations are subjected to a range of fluctuating loads, mean stress levels, and variable frequencies.
- It is important to predict the fatigue life of such a component.
- The cumulative damage theory attempts predict that.



Damage accumulation in a high to low loading sequences

Cumulative damage... (contd...)

- The ratio of the cycles of overstress to the virgin fatigue life at the same stress is called *cycle ratio*.
- *Palmgren-Miner rule* or *linear cumulative damage theory* assumes that total life of a part can be estimated by adding up percentage of life consumed by each over stress cycle and is given by,



Sequences of block loadings at four different mean stresses and amplitudes

$$\sum_{i=1}^{k} \frac{n_i}{N_i} = 1$$

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \ldots.. \frac{n_k}{N_k} = 1$$

Where *k* is the number of stress levels in the block spectrum loading.
N_1, N_2, N_3....N_i are the fatigue lives corresponding to stress levels σ_1, σ_2, σ_3.... σ_i, respectively and n_1, n_2,...n_i are the no of cycles carried out at the respective stress levels.

Coaxing

- If a specimen is tested without failure for a large number of cycles below the fatigue limit and the stress is increased in small increments after allowing a large number of cycles to occur at each stress level, it was found that the resulting fatigue limit is ~ 50% greater than the initial fatigue limit. This procedure is called *coaxing.*
- *Exists relation between coaxing effect and strain aging*
- *Mild steel and ingot iron show strong coaxing effect.*
- *Brass, Al alloy, low alloy steel show little improvement.*

Example

The S-N curve of a material is described by the relationship

$$\log N = 10(1 - S / \sigma_{\max})$$

Where N is the number of cycles to failure, S is the amplitude of the applied cyclic stress and σ_{max} is the monotonic fracture strength, i.e., $S = \sigma_{max}$ at $N = 1$. A rotating component made of this material is subjected to 10^4 cycles at $S = 0.5\ \sigma_{max}$. If the cyclic load is now increased to $S = 0.75\ \sigma_{max}$, how many more cycles will the material withstand?