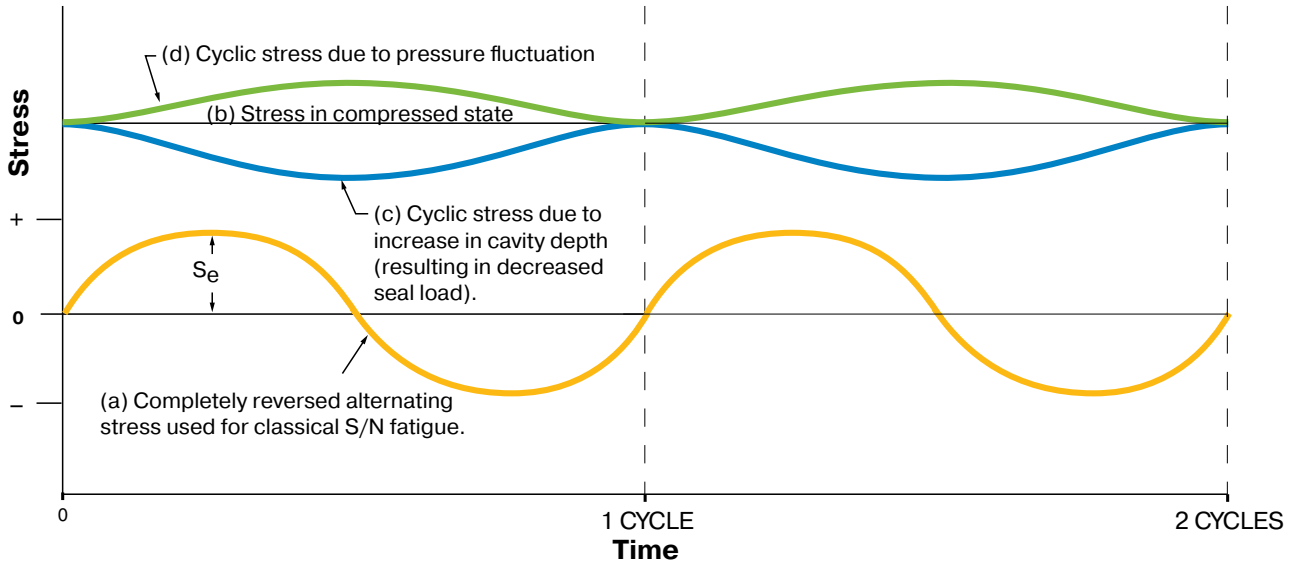
Fatigue and Stress Relaxation

Fatigue

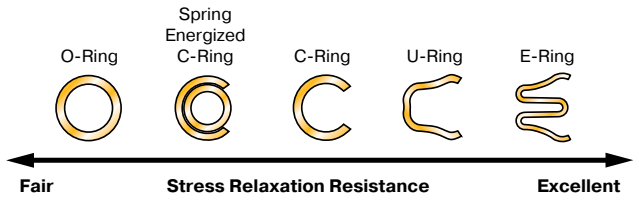
Fatigue is the main failure mechanism in a material that is subjected to fluctuating loads. Under cyclic loading, localized slip bands can form in regions of high localized stresses. As fluctuating loading continues, these bands increase in number and small microscopic cracks form. Given enough time and stress amplitude, the cracks will grow and propagate through the wall of the seal resulting in a fatigue failure and leakage.



There are several types of loading that can result in fatigue failure, the most common type being alternating tension and compression or reversed loading. Loading of this type is illustrated in line (a) in the figure above, and is the type used in fatigue testing to develop the endurance or fatigue limits (S_e) of materials. The endurance limit is the stress below which fatigue failure will not occur, regardless of the number of applied cycles (generally considered 10^7 cycles).

Another type of loading results in stresses modulating from one magnitude to another, in the same direction (low to high tensile stress). This is the type of loading most commonly seen in resilient metal seals. Referring to the figure, the seal is deflected or compressed at installation to a stress level corresponding to line (b). If the seal is then exposed to fluctuating flange separation or cavity growth, the stresses in the seal decrease, then increase as illustrated in line (c). If the seal is subjected to pressure cycling, the stresses in the seal can increase beyond the assembly stresses as illustrated in line (d).

Seals designed for greater springback are more resistant to fatigue due to a combination of cross sectional geometry and material properties including temper.



Stress Relaxation

Any highly stressed component, held at high temperatures, is subject to a form of permanent deformation known as stress relaxation. Unlike creep, stress relaxation occurs in a relatively short period of time, typically in as little as 100 hours of exposure time. This is an important design consideration in any critical sealing application at elevated temperature. Stress relaxationcompromises both the sealing load and springback properties of the seal, impacting its ability to maintain sealing integrity under both static and dynamic conditions.

Parker Hannifin has extensive experience designing and testing seals to mitigate the negative effects of stress relaxation. Seals can be designed to optimize resistance to stress relaxation through careful consideration of geometry, materials and appropriate heat treatment.