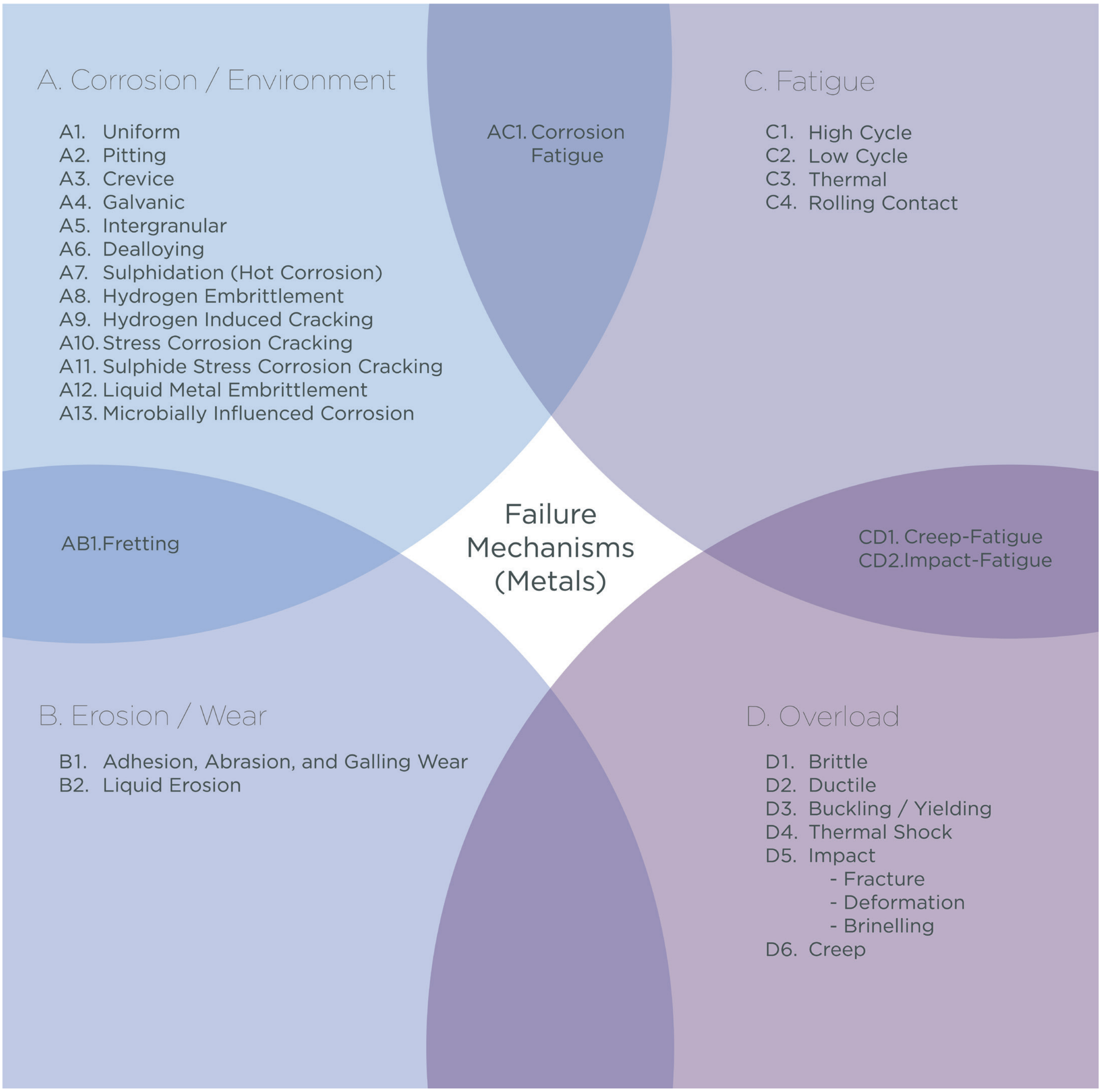
Failure Mechanisms (Metals)

SureScreen Scientifics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A. Corrosion / Environmental

A1. Uniform
Uniform corrosion is a generalised form of attack that occurs relatively evenly across a large area. The material thickness may be reduced with time, depending on how adherent the resulting corrosion deposits are to the underlying parent metal.

A2. Pitting
This is a highly localised form of corrosion attack when the metal surface is attacked at specific points. These can be from surface features or defects (e.g. mechanical damage), or microstructural phases and defects. Pits are typically characterised by a small opening at the surface, enlarging in diameter and depth into the material.

A3. Crevice
A localised form of corrosion that occurs in small gaps or crevices that create stagnation of liquids and a concentration of damaging species in the enclosed environment. Crevices may be formed under fasteners, loose coatings such as paint and insulation, bolted joints, and components in close contact.

A4. Galvanic
Corrosion attack when two dissimilar metals are in electrical contact through an electrolyte. An electrochemical cell is set up resulting in a flow of electrons from the material with the lower electrical potential (oxidation at the anode, with corrosion/loss in material) to the material with the higher potential (reduction at the cathode).

A5. Intergranular
Attack of a metal along the grain boundaries often associated with localised changes in the material composition at these boundaries, due to segregation of impurities in the metal or precipitation of phases that reduce the corrosion resistance.

A6. Dealloying
Most metals used in engineering are alloys; mixtures of more than one pure metal. The corrosion process may selectively attack, and leach out one of the elements, leaving a porous and weakened structure behind. One of the most common dealloying corrosion mechanisms is the dezincification of brass, an alloy of copper and zinc.

A7. Sulphidation
Sometimes referred to as Hot Corrosion, is the rapid oxidation of a material due to the deposition of sodium sulphate salts (derived from a combination of sulphur from fuel, and sodium chloride in the ingested air). Consisting of two types; Type 1 characterised by thick and porous layers of oxide with the underlying matric depleted of chromium, whilst Type 2 is characterised by pitting with no underlying depletion of the matrix.

A8. Hydrogen Embrittlement
Hydrogen embrittlement is an umbrella term that covers several different mechanisms, but all of which involve the reduction in ductility, and subsequent fracture of metals because of atomic hydrogen and stress within the metal. It may also be associated with Stress Corrosion Cracking and Sulphide Stress Cracking.

A9. Hydrogen Induced Cracking
A form of hydrogen embrittlement which occurs in carbon and low alloy steels when atomic hydrogen diffuses into the metal and forms molecular hydrogen. This often forms at discontinuities, such as inclusions. The molecular hydrogen internally pressurises the metal to a point where cracking occurs.

A10. Stress Corrosion Cracking
The fracture resulting from the combined action of stress and corrosion (anodic reaction), the effect of which, is greater than the sum of the two components; a synergistic effect.

A11. Sulphide Stress (Corrosion) Cracking
A form of hydrogen embrittlement which is similar to stress corrosion cracking (SCC) but which is a cathodic cracking mechanism, compared to the anodic reaction with SCC. In the presence of H_2S steels react to form metal sulphides and H. The H can combine to form H_2, but the sulphur reduces this recombination effect leaving atomic H free to diffuse into the metal, driving the cracking mechanism.

A12. Liquid Metal Embrittlement
An unusual and uncommon failure mechanism where a liquid metal can cause the rapid attack, usually along the grain boundaries, of another metal with a higher melting point when under stress, resulting in fast brittle fracture of an otherwise ductile material. Specific metal couples exhibit such effects e.g. zinc-steel and aluminium-lead.

A13. Microbially Influenced Corrosion
The effect of the presence of microorganisms on the surface of a metal, resulting in the corrosion attack of the metal surface at the metal-organism interface. This typically leads to rapid pitting corrosion.

AB1. Fretting
Degradation of surfaces in close contact subjected to relative reciprocating movement e.g. from vibrations. Small particles of material from one or both surfaces break away and are then oxidised (corroded) which then act as an abrasive, driving damage of the surfaces.

AC1. Corrosion Fatigue
The combined action of repeating cycles of stress in a corrosive environment to produce cracking in fewer stress cycles than would otherwise occur in a non-corrosive environment.

B. Erosion / Wear

B1. Adhesion, Abrasion, and Galling Wear
Two surfaces in contact and relative motion will cause particles to break off due to the inherent roughness. These particles act as abrasive debris leading to further damage and accelerating the surface degradation.

B2. Liquid Erosion/Wear
Mechanical destruction of a surface from the high energy impact of liquid droplets onto a surface. Damage can occur as a consequence of 1) the collapse of bubbles in the liquid, generating localised stress waves, termed 'cavitation', or 2) by stress induced in the surface from the direct impact of the liquid droplet, termed 'liquid impingement'.

C. Fatigue

C1. High Cycle Fatigue
A progressive crack growth mechanism that occurs at high cycles, and typically relatively low stress. The stress is below the yield strength of the material and any strains or deformation are in the elastic zone i.e. no permanent deformation.

C2. Low Cycle Fatigue
A progressive crack growth mechanism that occurs at a relatively small number of stress cycles, but high stress, that is typically greater than the yield strength leading to plastic deformation.

C3. Thermal Fatigue
Fluctuations in temperature will cause a component or assembly to expand and contract, with a resulting change in the stress. In some metal combinations or assemblies, due to either excessive temperature changes or poor design, the generated stresses may be greater than the yield or tensile strength of the material leading to deformation or fracture.

C4. Rolling Contact Fatigue
When two surfaces are in rolling, or combined rolling and sliding contact, stresses are generated at and below the contact surface. Typically, the highest stress is just below the surface and can be high enough to cause the material to crack. These cracks propagate deeper into the material, but also out to the surface resulting in spallation/detachment of the surface.

CD1. Creep-Fatigue
The combined effects of creep (a time-temperature effect) and fatigue (from cyclic stress) can be an important failure mechanism for components at high temperature. Loading, with dwell periods at high temperature can lead to creep damage, and cyclic stress can drive fatigue cracking. Cracking initiates earlier than predicted by creep or fatigue process alone.

CD2. Impact-Fatigue
Cracking or damage that occurs when a material is subjected to repeated impacts. High strain rates generated in the material from an impact, are greater than that experienced in 'normal' fatigue which can lead to rapid onset of crack initiation.

D. Overload

D1. Brittle Fracture
The fracture of a material due to stress greater than the material's ultimate tensile strength without any appreciable plastic deformation. The two parts of the fracture could be placed back together with the component effectively showing the same nominal geometry or dimensions.

D2. Ductile Fracture
The fracture of a material due to stress greater than the material's ultimate tensile strength with significant plastic (permanent) deformation.

D3. Buckling/Yielding
This is the failure of a component due to an applied stress that is greater than the material's yield stress, that does not necessarily cause fracture. Buckling is a function of the geometry of the component and is often associated with thin-walled cylinders, struts, and columns.

D4. Thermal Shock
Thermal shock is a type of rapid mechanical loading caused by a rapid change of temperature. In a component it may lead to a thermal gradient, which causes different parts of a component to expand by different amounts. This variation in expansion can generate stress that exceeds the tensile strength of the material resulting in cracking.

D5. Impact
A high strain rate effect caused by the dynamic contact (collision) between two surfaces. Materials react differently under impact compared to static or slow loading rates. Impact by a given mass will generate greater energy than the same mass applied statically or at a slow loading rate, and hence be more prone to cause fracture.

D6. Creep
The time-dependent strain effect that occurs under the effects of an applied stress.

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