Best Material predicts and prevents deterioration and damage accidents in all structures.

b-mat

Basic Course of Materials by Best Materia

- All structural damage happens because of material failure.
- Materials deteriorate over time in their usage environment, leading to damage.
- There are 147 types of material deterioration and damage mechanisms (see Table 1), and there are no others.
- By predicting and preventing all of these deterioration and damage mechanisms, we can prevent structural failures.
- These 147 deterioration and damage mechanisms can be categorized into the following nine mechanisms.

Fatigue
Creep
Natural corrosion
Dry corrosion
Wet corrosion
Stress corrosion cracking
Wear
Erosion
Property deterioration

You can view it on Matguide (https://matguide.com)
Any question to :
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- Here's a look at each of the nine mechanisms.

Regarding the 9 mechanisms, I expect it to be common knowledge for an engineer.

Table 1 Deterioration and damage mechanisms

Total 147 mechanisms, 9 mechanisms in middle category

Middle category	Fatigue	Creep	Natural corrosion	Dry corrosion		Wet corrosion						Stress corrosion cracking (SCC)		*Wear*	Erosion		Property deterioration		
Minor category	Mechanical fatigue (high cycle fatigue)	Creep deformation	Atmospheric (External) corrosion	High temperature oxidation	Fuel ash corrosion	Freshwater corrosion	Hydrochloric acid corrosion	Ammonium chloride corrosion	Carbonic acid corrosion,	Oxygen concentration cell corrosion	Crevice corrosion	Sulfide stress corrosion cracking	Nitrate stress corrosion cracking	Adhesive wear	Erosion /Corrosion	Drop Slag erosion	Hydrogen embrittlement	Sensitization	Reheat(SR) cracking
	Low cycle fatigue	creep rupture	Condensation corrosion	Steam oxidation	Coal ash corrosion	Seawater corrosion	Wet chlorine and hypochlorite corrosion	Ammonium hydrosulfide corrosion	Acid sour water corrosion	Groove corrosion	Galvanic corrosion	Hydrogen induced cracking (Hydrogen bulister)	Organic acid stress corrosion cracking	Sliding wear	Cavitation erosion	Coal particle erosion	Hydride embrittlement (Titanium)	Sigma phase embrittlement	Cladding delamination
	Contact fatigue	Long-term creep rupture	External stress corrosion cracking	Metal dusting	Black liquor smelt corrosion	Contaminated seawater corrosion	Sulfuric acid corrosion	Ammonia attack	Boric acid corrosion	Intergranular corrosion	Corrosion under deposit	Caustic (soda) cracking	High temperature water cracking	Corrosion wear	Solid particle impimgement erosin		Decarburization	gamma prime (gamma' phase) embrittlement	Under-cladding cracking
	Fretting fatigue	Short time Creep rupture	Corrosion under insulation	Halogenated corrosion (High temperature Halogen corrosion	High temperature chloride salt corrosion	Flow accelerated corrosion	Phosphoric acid corrosion	CO2 corrosion	Caustic corrosion, Caustic gouging	Filiform corrosion	Down-Time Corrosion	Amine cracking	Tarnish Rupture	fretting corrosion	Liquid drop impimgement erosion		Carburization	Strain aging	475°C embrittlement
	Corrosion fatigue	Creep embrittlement	Stress corrosion cracking under insulation	Sulfidation	High temperature carbonate corrosion	Dissolved oxygen corrosion, (oxygen concentration cell corrosion)	Nitric acid corrosion	Cooling water corrosion	Chelate corrosion	Formicary (ants' nest) corrosion	Stress corrosion	Carbonate cracking	Cyanide SCC	Fatigue wear	Inletattack		Nitriding	Tempering embrittlement	Disimilar metal weld emblittlement
	Thermal fatigue	Creep-fatigue rupture		High temperature sulfidation	Hydrogen attack	Acid dew point corrosion (sulfuric and hydrochloric acid dew point corrosion)	Phosphate corrosion	Boiler water condensation corrosion	Naphthenic acid corrosion	Chemical cleaning corrosion	Graphitization corrosion	CO-CO_2-H_2O SCC	Ammonia SCC	Abrasive wear	Impingement attack		Liquid metal embrittlement	Softening (over aging)(carbide spheroidization)	
	Thermal attack (fire cracking)	Dissimilar metal weld cracking (DMW)		High temperature sulfide/hydrogen sufide corrosion	Molten metal corrosion	Microbial corrosion	Phenolic corrosion	Pitting corrosion	Water line attack	Atmospheric tank bottom plate corrosion	Alkali sour water corrosion	Polythionic acid SCC	Irradiation assisted stress corrosion cracking (IASCC)		Sluly eroison		Graphitization	sigma phase and chi phase embrittlement	
	Rolling contact fatigue	Relaxation		Molten salt corrosion		Soil corrosion	Wet sulfide corrosion, wet hydrogen sulfide corrosion	Hydrofluoric acid corrosion	Knife line attack	Selective corrosion (dealloying) de-component corrosion		Chloride SCC			Fly ash erosion		Isothermal aging embrittlement	Irradiation embrittlement	
	Ratcheting	Type IV cracking		Vanadium attack		Organic acid corrosion	Wet chloride corrosion, wet HCl-H2S corrosion	Amine corrosion	Stray current (concentration cell) corrosion	Layered (exfoliation) corrosion		Hydrogen induced cracking in hydrofluoric acid			Soot blower erosion		Hot embrittlement (low ductility) of killed steel	volume expansion (swelling)	

Fatigue

All materials can develop cracks and eventually break when subjected to repeated stress, even at stress levels that wouldn't cause failure under static load. This is called fatigue. There are 9 mechanisms as a sub-classification.

Examples of Fatigue Failures

- The world's first jet airliner, the Comet, broke up in midair due to structural fatigue
- The JAL jumbo jet crashed due to fatigue failure of a bulkhead.
- The Monju fast-breeder prototype reactor had a sodium leak caused by fatigue failure in the pipe thermometer sheath tube.
- The first-stage engine of the H-II Rocket No. 8 crashed due to fatigue failure of the inducer blades (titanium alloy) in the LE-7 liquid hydrogen turbopump.

Fatigue fracture port

You can tell it's fatigue from the pattern on the fracture surface.



Inducer recovered from the seabed

Edited by Hideo Kobayashi, Failure Accidents, Kyoritsu Publishing

Creep

Materials, even under stress that doesn't cause deformation or breaking at room temperature, gradually deform and eventually break at high temperatures (above a certain temperature specific to each material) after some time. This phenomenon is called creep.

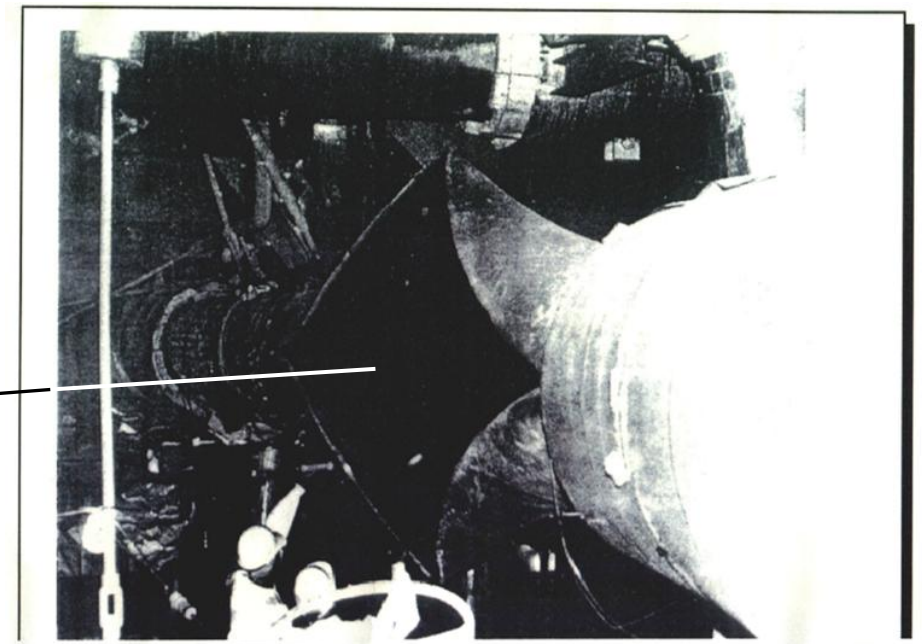
There are 9 mechanisms as a sub-classification.

Examples of creep failures:

Creep failure at the welds of reheat steam pipe in a U.S. power plant after 20 years of use

Opening

Eight engineers died due to the high-temperature steam eruption



米国発電所の再熱蒸気管（低合金鋼）溶接継手部のクリープ破壊

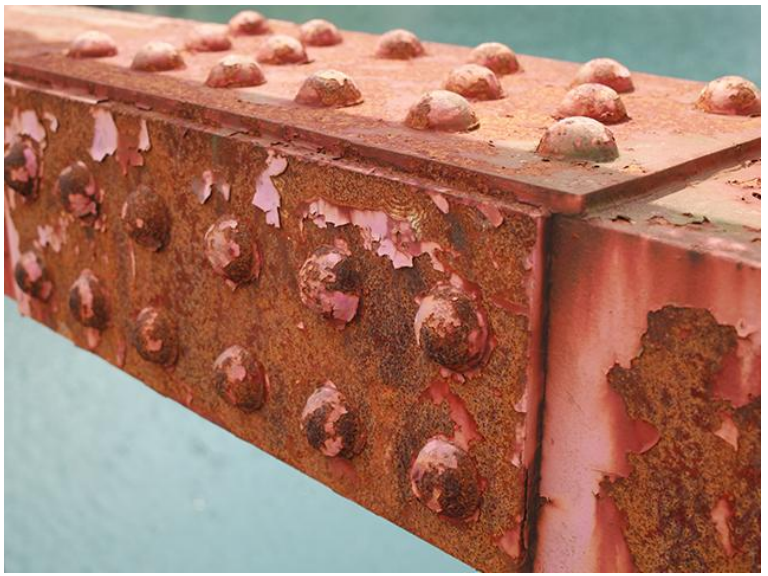
Natural corrosion

Metals exist on Earth as compounds (like oxides and sulfides), and they are reduced (like through smelting) for industrial use. So, in nature where oxygen is present, they tend to oxidize again and turn back into oxides (like when rust forms). This phenomenon is called natural corrosion.

There are five mechanisms as a sub-classification.

Examples of natural corrosion;





Formation of rust (iron oxide)

For aesthetic reasons, rust is usually prevented by painting, but the paint itself also deteriorates. For things like bridges and power transmission towers, the painting schedule is managed to keep natural corrosion in check.

Dry corrosion

It's a phenomenon where metal directly reacts with reactive gases like oxygen, water vapor (in gaseous form), carbon dioxide, or with molten salts, and while forming a solid layer of reaction products (mainly oxides) on the metal surface, the metal gets consumed.

There are 16 mechanisms as subcategories.

Example of dry corrosion



Dry corrosion of boiler tubes in boiler combustion environment



Microscopic observation for oxides layers on steel surface

Wet corrosion

When materials leach out in a liquid, it's called wet corrosion. The degree of corrosion varies depending on the combination of the liquid component and the material (including coatings and other anti-corrosion measures). Corrosion can happen in various corrosive liquids like acids and alkalis, and there are many damage mechanisms.

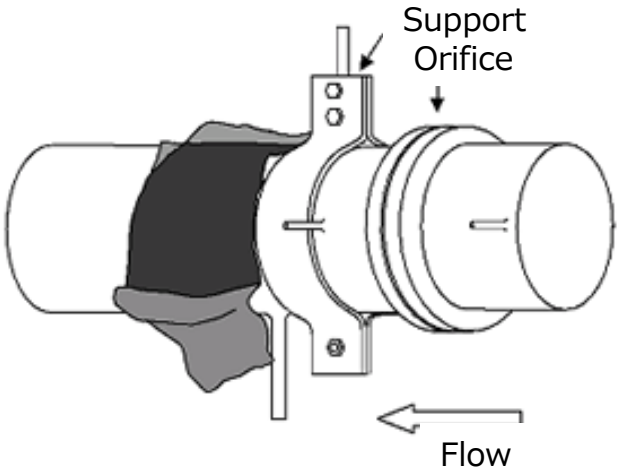
There are 52 mechanisms in the subcategories.

Example of wet corrosion

At Kansai Electric's Mihama Power Plant Unit 3, after 19 years of use, a steam blowout occurred in the downstream part of the orifice due to flow-accelerated corrosion (FAC)*1 in 2004, killing four maintenance workers.



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*1 Corrosion and thinning accelerate in flow turbulent areas. It only occurs in turbulent spots like elbows, downstream of orifices, and reducers.

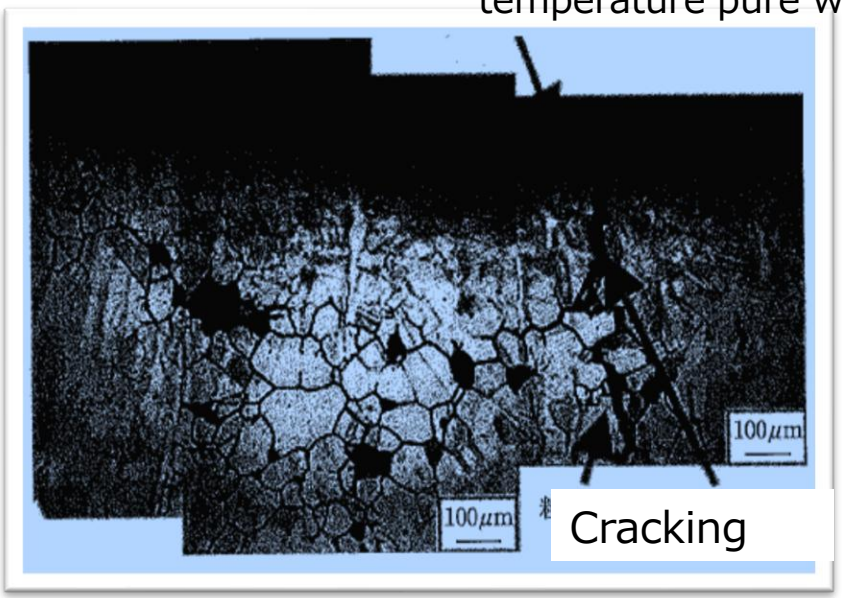
Stress Corrosion Cracking（SCC）

Corrosion is the phenomenon where a material dissolves into its environment. In regular corrosion, the material generally dissolves across the entire surface or in localized spots, causing a reduction in thickness. But under certain stresses, corrosion can progress in very narrow areas in a crack-like manner, and this is called stress corrosion cracking. It occurs when three conditions—environment, material, and stress—are all present.

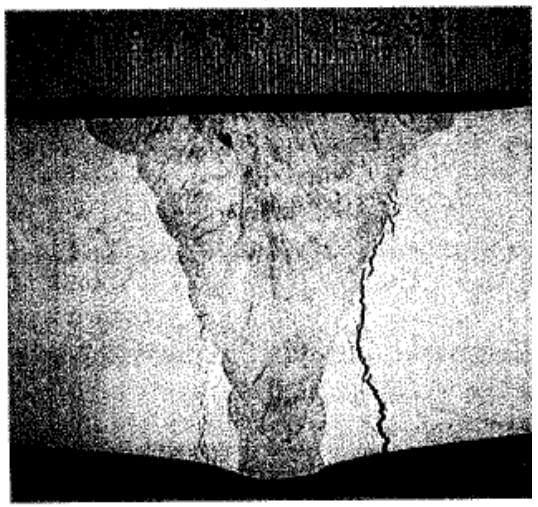
There are 16 mechanisms classified as subtypes.

Example of SCC

Material : SUS304(Stainless steel)、Environment : High temperature pure water



Stress corrosion cracking of nuclear reactor shroud - cross-sectional microscope observation results



Microscope observation results of stress corrosion cracking at welded joints of nuclear power plant recirculation piping

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Wear

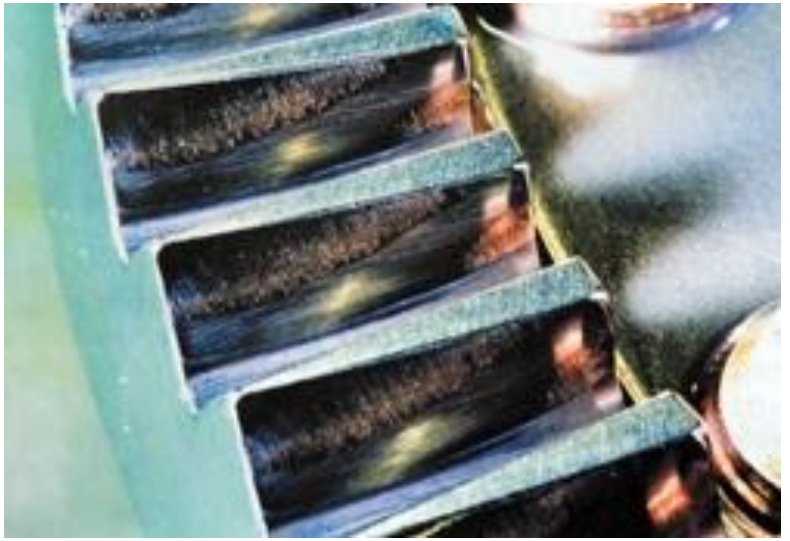
When solid materials are used while rubbing against each other, one or both of them wear down, and the thickness decreases. This phenomenon is called wear.

There are 6 mechanisms as a sub-classification.

Case of wear



Wear on bearing of shaft



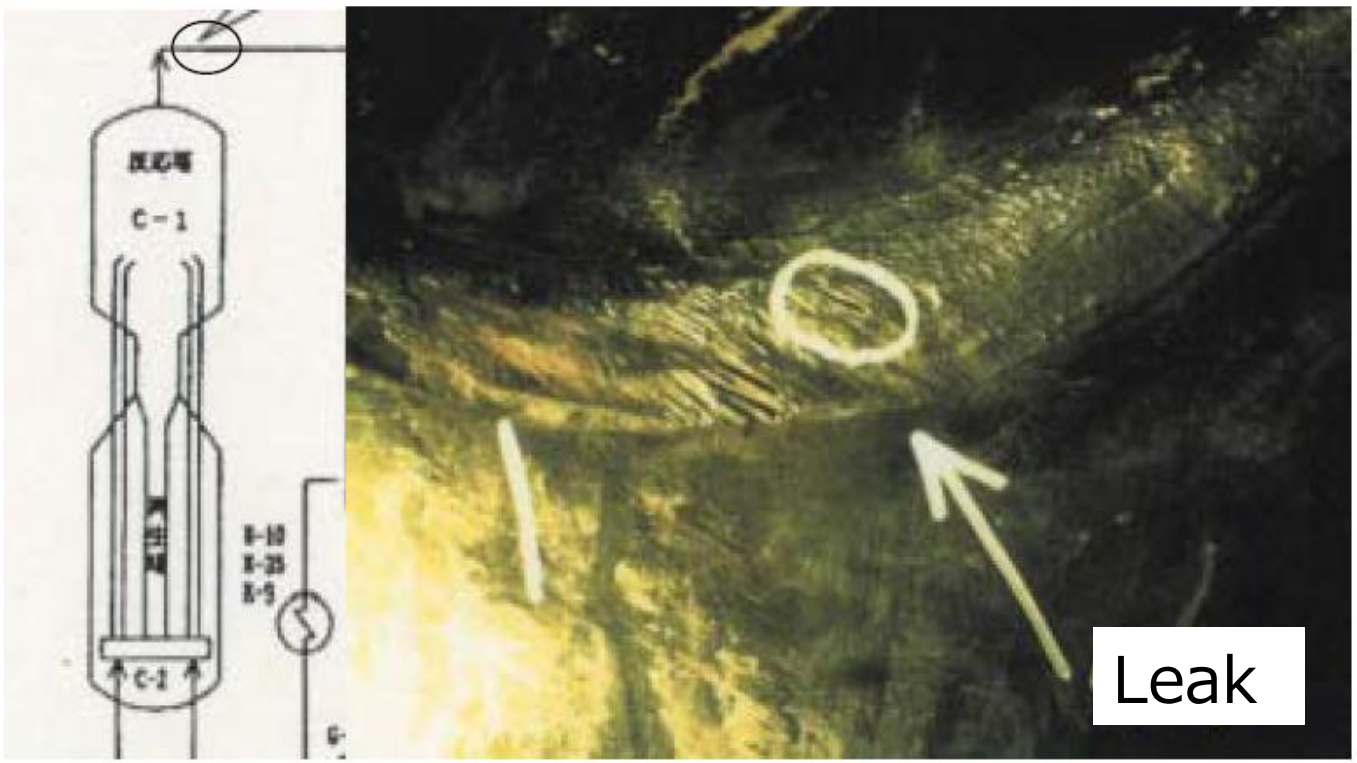
Wear of gear

Erosion

Erosion is a phenomenon where a material gets mechanically worn out due to repeated collisions (or impacts) with a fluid, causing some of it to break off.

There are 11 mechanisms as subcategories.

Case of erosion　Thinning, leakage and fire by erosion of vessel



Fluid:
A mixed gas of LPG, gasoline, and decomposition gas.
Pressure:
0.113 MPa
Temperature:
474℃

Report of accident in high pressure gas　No 2003-213

Property deterioration

Metals are adjusted (through heat treatment and the like) so that they have optimal properties when first used. At room temperature, atomic movement doesn't occur, so their properties don't change, but at high temperatures, atoms move to more energetically stable states, which causes changes in properties. These changes are often inconvenient for use (like reduced material strength, ductility, or corrosion resistance) and can be the cause of accidents after long-term use. This decline in properties is called material degradation (metallurgical degradation).

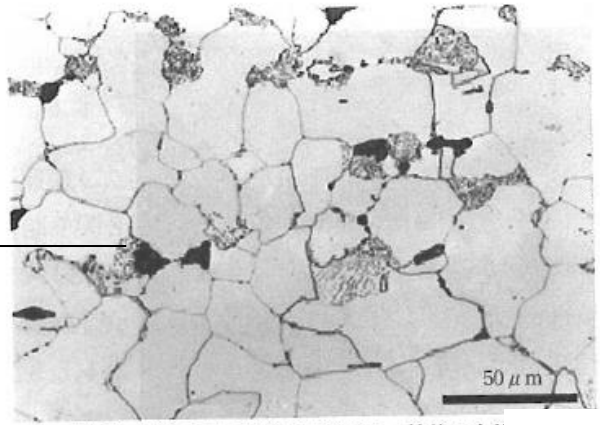
There are 23 mechanisms as subcategories.

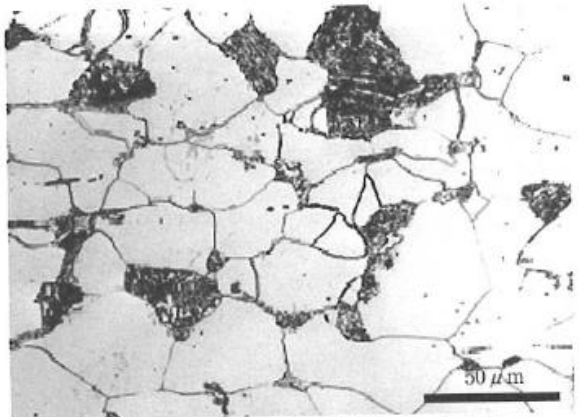
Example of property deterioration

After using the boiler steel pipe at 476°C for 30 years, it suffered a brittle fracture. Microscope observation concluded that the brittle fracture was due to graphitization, where carbides turned into graphite.

Microstructure : Formation of Graphite

Graphite





Microstructure : Ferrite- Pearlite

(a) 破壊した管（黒い部分は黒鉛化部，縞状と点状 パーライト）

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