A classification scheme for wear and corrosion modes

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Background

- In 2002, the Sugar Research Institute conducted a project with 15 Australian sugar factories to identify improved materials for reducing factory maintenance costs

Process to identify improved materials

- Assessing the fundamental wear mechanisms involved
- Identifying materials with resistance to those wear mechanisms

Need for a classification scheme

- Needed a basis to identify the fundamental wear mechanisms
- Implemented a classification scheme

Definitions

- Wear
  - Damage to a solid surface, generally involving progressive loss of material, that is due to relative motion between that surface and a contacting substance or substances
- Corrosion
  - The chemical or electrochemical interaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties

More simplistically

- Wear
  - A mechanical process involving material loss and optionally surface damage
- Corrosion
  - A chemical or electrochemical process involving material loss or damage to material properties

Complications for a classification scheme

- Several classification schemes for wear with inconsistent usage of terms
- Corrosion may be a factor in wear situations
- Corrosion may also occur without wear

Wear modes

- Sourced from a paper by Gates and Gore (1995)
  - ‘Wear of metals: philosophies and practicalities’, *Materials Forum*, 19: 55-89.

Categories of wear

- Metal to metal wear
  - Two metal surfaces in contact
- Abrasive wear
  - Particles in contact with metal surface
- Fluid erosion
  - Particles in a fluid in contact with metal surface

Classifying wear

- Within each category, wear classified by wear modes consisting of:
  - Situation
  - Manifestation

Metal to metal wear

Wear mode	Situation	Manifestation
Severe sliding wear	Metal to metal sliding	High wear rates and metallic debris
Mild sliding wear	Metal to metal sliding	Low wear rates and oxidised debris
Fretting wear	Metal to metal oscillation	Bed of oxide debris
Rolling contact fatigue wear	Metal to metal rolling	Pitting after an initial period followed by spalling
Solid body impact fatigue wear	Repeated impact	Spalling after an initial period

Abrasive wear

Wear mode	Situation	Manifestation
Gouging abrasion	Large particles and extreme stresses or impact	Deep grooves and gross deformation
Grinding (high stress) abrasion	Stresses sufficient to fracture abrasive particles	High wear rates and visible scratches
Low stress abrasion	Stresses insufficient to fracture abrasive particles	Low wear rates and fine scratches

Fluid erosion

Wear mode	Situation	Manifestation
Solid particle erosion	Particles in high velocity gas	Surface profile related to flow patterns
Slurry erosion	Particles in high velocity liquid	Surface profile related to flow patterns
Liquid flow erosion	Flowing liquid	Low wear rates and surface profile related to flow patterns
Liquid droplet erosion	High velocity droplets or liquid entrained gas flows	Median wear rates, pitting
Cavitation erosion	Cavitation (bubble collapse)	High wear rates and pitting

Aspects for consideration

- Operating surface
  - Nature of surface being worn
- Mating component
  - Nature of the mating component
- Process material
  - Nature of the material being processed or interface material

Aspects for consideration

- Mechanical motion
  - Nature of the relative motion
- Mechanical severity
  - Severity of the interaction
- Environmental
  - Temperature, nature and action of corrosive material

Wear and corrosion

- Wear is the result of a process
- Corrosion is a process producing a result
- Not directly equivalent but treat corrosion like a wear mode

Corrosion modes

- Corrosion producing material loss
  - Dry corrosion
    - Absence of liquid electrolyte
  - Wet corrosion
    - Presence of liquid electrolyte
- Corrosion producing property deterioration
- Mechanically assisted corrosion

Dry corrosion

Wear mode	Situation	Manifestation
High temperature corrosion	Metal in presence of high temperature air or oxidising gas	Formation of metal oxide scales

Wet corrosion

Wear mode	Situation	Manifestation
Uniform corrosion	Metal in contact with corrosive medium	Progressive thinning of exposed surface
Galvanic corrosion	Electrically connected dissimilar metals in corrosion medium	Preferential attack of most susceptible metal
Pitting corrosion	Chloride solutions (+ oxidising metal ions) on stainless steel particularly	Holes (generally small) in the metal
Crevice corrosion	Crevice holding small volume of stagnant corrosive medium	Intense localised corrosion

Corrosion causing property deterioration

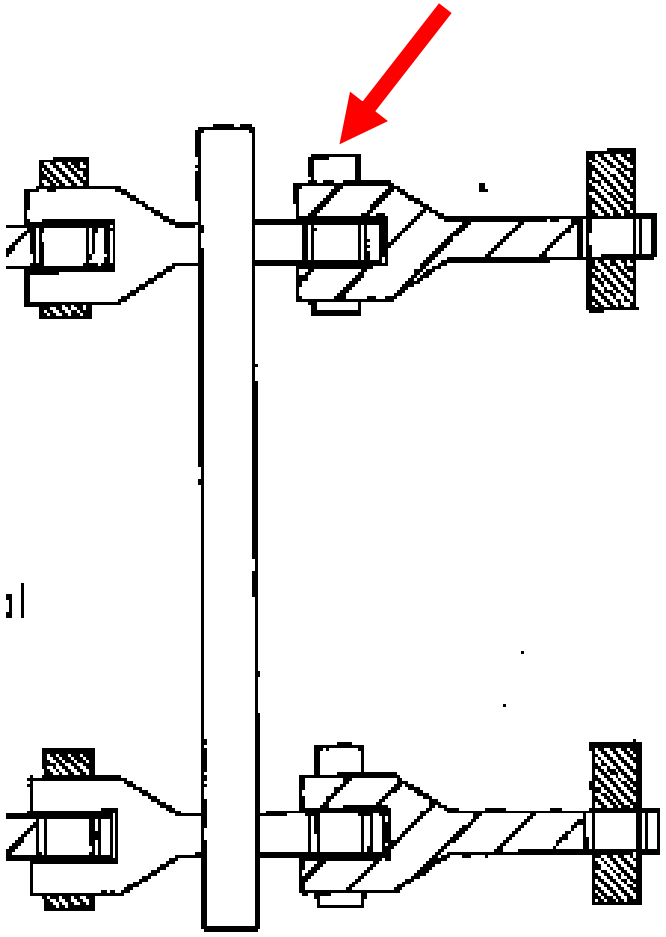
Wear mode	Situation	Manifestation
Intergranular corrosion	Grain boundary regions more reactive than grains	Loss of strength and/or loss of grains
Stress corrosion cracking	Tensile stress + specific corrosive medium	Fine cracking over surface with otherwise little attack

Mechanically assisted corrosion

Wear mode	Situation	Manifestation
Corrosion fatigue	Cyclic stress + corrosive medium	Reduction in fatigue resistance

- Other forms of mechanically assisted corrosion accommodated in wear modes
  - Erosion corrosion
  - Fretting corrosion
  - Cavitation

An example classification – intermediate carrier chain pin



Intermediate carrier chain pin

Operating surface	431 stainless steel, through hardened
Mating surface	Hardened 4140 steel
Interfacial material	Bagasse, juice, dirt, oxide debris, metal debris, lubricant
Mechanical motion	Sliding
Mechanical severity	Severe on working side of pin
Environmental	Acidic cane juice, temperature 30 °C to 80 °C
Proposed wear mode	Severe sliding wear with some grinding abrasion. Mild sliding wear away from working faces. Pitting or crevice corrosion if juice ingress occurred.

In conclusion

- Classification of wear and corrosion modes a first step in identifying materials better suited to the application