Unit 2

WEAR

Law of Wear

- The wear volume is proportional to the normal force.
- The wear volume is proportional to the sliding distance.
- The wear volume is inversely proportional to the hardness of the softer of contact partners.

Types of Wear Mechanisms

The concept of "laws of wear" typically refers to the principles and understandings governing the wear and tear of materials and mechanical components over time. Wear is a complex phenomenon that can involve mechanical, chemical, and physical processes, depending on the materials involved and the conditions they're exposed to. There isn't a single, unified set of "laws of wear" because wear mechanisms can vary widely across different applications and materials. However, some foundational concepts are commonly studied and applied in the field of tribology, the science of wear, lubrication, and friction.

Some key concepts in the study of wear include:

Adhesive Wear:

Occurs when two surfaces slide against each other, leading to material transfer from one surface to the other or the loss of material from both surfaces due to adhesion.

Abrasive Wear:

Caused by hard particles or hard protuberances forced against and moving along a solid surface.

Corrosive Wear:

Involves chemical or electrochemical reaction with a corrosive fluid or environment, leading to material degradation and loss.

Fatigue Wear:

Results from repetitive loading or stress cycles, leading to the formation and propagation of cracks, and eventually, material failure.

Erosive Wear:

Caused by the impact of solid or liquid particles on a surface, leading to material removal through a process similar to abrasion or corrosion, depending on the nature of the impacting particles and surface.

Wear Debris Analysis

Wear debris analysis is a critical aspect of machine condition monitoring and failure diagnosis. It involves examining the particles that are generated by wear and tear in machinery, especially in components such as bearings, gears, and other moving parts. The analysis can provide invaluable information about the health and operational status of machinery, helping to predict failures before they occur and to schedule maintenance to prevent unplanned downtime.

There are several methods for conducting wear debris analysis, including:

Microscopic Examination:

This involves using optical or electron microscopes to visually examine the size, shape, and composition of wear particles. This method can identify different wear mechanisms, such as abrasive, adhesive, corrosive, or fatigue wear.

Ferrous Density Analysis:

For systems primarily composed of ferrous materials, measuring the concentration of ferrous particles in a lubricant can indicate the rate of wear.

Spectroscopic Analysis:

Techniques such as atomic emission spectroscopy (AES) or inductively coupled plasma (ICP) spectroscopy can quantify the concentration of various metal elements in lubricants, providing insights into the wear of specific components.

Particle Counting and Sizing:

This involves counting the number of particles in a sample and categorizing them by size to assess the severity and type of wear.

Chemical Analysis:

Analyzing the chemical composition of debris can help identify the specific materials involved in the wear process, which can be critical for diagnosing problems in complex machinery.

Wear debris analysis is commonly used in industries such as manufacturing, automotive, aerospace, and energy, where machinery reliability is critical. By identifying wear patterns early, maintenance teams can address issues before they lead to equipment failure, saving time and money, and enhancing safety.

Wear on Metals

Wear on metals refers to the progressive loss of material from the surface of a metal component as a result of mechanical action, such as contact with another surface (which could be metal or another material). Wear is a common degradation process and can significantly affect the performance and lifetime of metal components in various applications, including machinery, engines, tools, and structural elements. The mechanisms and factors contributing to wear on metals are diverse and can include the following:

Adhesive Wear

Occurs when two metal surfaces slide against each other under pressure. Microscopic welds form between the surfaces and then break, leading to material transfer or loss. Adhesive wear is common in components with sliding motion, such as gears and bearings.

Abrasive Wear

Happens when a harder material (which could be particles or a rough surface) scratches or cuts into a softer surface. This type of wear is typical in environments where grit or hard particles are present, such as in mining or construction machinery.

Corrosive Wear

Involves chemical or electrochemical reactions between the metal and its environment, which can remove material from the surface or change its properties in a way that makes it more susceptible to mechanical wear. Corrosive wear is a concern in harsh chemical environments or where there is exposure to water or humidity.

Fatigue Wear

Results from repeated cyclic stress or load, leading to material failure and wear in the form of cracks, pits, or flakes. Fatigue wear is often seen in rotating components, such as shafts and bearings, under fluctuating loads.

Fretting Wear

Occurs at the interface of two contacting surfaces under load that experience small amplitude oscillatory motion relative to each other. This can lead to the formation of wear particles and surface damage, often accompanied by corrosion.

Erosive Wear

Caused by the impact of solid, liquid, or gaseous particles on the surface of the metal, leading to material removal. Erosive wear is significant in equipment such as turbines, pipes, and valves that handle moving fluids containing abrasive particles.

Factors Influencing Wear on Metals

Several factors can influence the rate and type of wear experienced by metal components, including:

- Material properties (hardness, toughness, corrosion resistance)
- Surface finish and treatment
- Environmental conditions (presence of corrosive substances, temperature, humidity)
- Mechanical conditions (type of motion, load, speed, lubrication)

Control Measures for Wear on Metals

To mitigate wear on metals, strategies may include:

- Material selection based on operating conditions and wear mechanisms
- Surface treatments and coatings to enhance hardness or corrosion resistance
- Use of lubricants to reduce friction and wear
- Design modifications to distribute stress or eliminate problematic contact conditions

Wear on Non-Metals

Wear on non-metals involves the degradation or removal of material from non-metallic surfaces due to mechanical actions, similar to wear on metals but often involving different mechanisms and factors due to the distinct physical and chemical properties of non-metals. Non-metals, including polymers, ceramics, and composites, are widely used in various applications ranging from industrial machinery to consumer products due to their unique attributes, such as corrosion resistance, low weight, and high strength-to-weight ratios. The wear mechanisms affecting non-metals include:

Adhesive Wear

Occurs when two surfaces slide against one another, leading to material transfer from one surface to the other or the removal of material from both surfaces. In non-metals, especially polymers, this can also involve the smearing of material on the contact surfaces.

Abrasive Wear

Happens when a harder material, which could be particles or asperities on a counter face, scratches or cuts into the softer non-metal surface. This is common in applications where non-metallic components come into contact with gritty or rough materials.

Fatigue Wear

Results from cyclic stress that leads to material failure and wear in the form of cracks, pits, or detachment of material. Non-metals, particularly polymers and composites, can exhibit fatigue wear under repeated loading or flexing.

Fretting Wear

Occurs at the interface of contacting surfaces that experience small amplitude oscillatory motion relative to each other. For non-metals, this can lead to the generation of wear debris and surface damage, potentially accelerating wear rates.

Chemical Wear

Involves chemical or environmental interactions that degrade the non-metallic material, making it more susceptible to mechanical wear. This can be due to reactions with chemicals, exposure to UV light, or hydrolysis, especially in polymers and composites.

Erosive Wear

Caused by the impact of solid, liquid, or gaseous particles on the non-metallic surface, leading to material removal. The severity of erosive wear on non-metals depends on the impact velocity, angle, and the hardness and shape of the impacting particles.

Factors Influencing Wear in Non-metals

The wear behaviour of non-metals is influenced by several factors, including:

- Material properties such as hardness, toughness, and chemical resistance.
- Environmental conditions, including the presence of chemicals, temperature, and UV exposure.
- Mechanical conditions like load, speed, type of motion, and presence of abrasive particles.
- Surface treatments or modifications to improve wear resistance.

Control Measures for Wear on Metals

To reduce wear on non-metals, several strategies can be employed:

- Material selection that matches the application's environmental and mechanical conditions.
- Use of coatings or surface treatments to enhance surface properties.
- Design modifications to minimize stress concentrations and abrasive contacts.
- Incorporating lubrication or using self-lubricating materials to reduce friction and wear.

Theoretical wear models

Theoretical wear models in tribology are essential for predicting the wear behavior of materials under various conditions. Tribology, the study of friction, wear, and lubrication, utilizes these models to understand and predict how materials will perform when in contact. Here's an overview of several key theoretical wear models:

Adhesive Wear Models:

These models are based on the concept of asperity contact between surfaces in relative motion. As the asperities (microscopic high points) on one surface slide over another, they adhere to each other, leading to material transfer or the formation of wear particles. The actual wear mechanism can involve ploughing, cutting, and fracture.

Abrasive Wear Models:

Abrasive wear occurs when a rough, hard surface or hard particles pass over a softer surface, causing material removal by micro-cutting or ploughing. Models of abrasive wear take into account the geometry of the abrasive particles, the hardness of the surfaces, and the nature of the contact.

Erosive Wear Models:

This type of wear is caused by the impact of particles or liquid droplets on a surface. Erosive wear models consider the velocity, size, and angle of impact of the particles, as well as the material properties of the target surface.

Fatigue Wear Models:

Fatigue wear occurs due to the repeated loading and unloading of surfaces in contact, leading to crack initiation and propagation, eventually causing material removal. Models for fatigue wear consider the cyclic stress, surface quality, and environmental conditions.

Corrosive Wear Models:

These models account for wear accelerated by chemical or electrochemical reactions at the surface. The wear rate is influenced by the environment, material properties, and protective coatings or inhibitors.

Tribochemical Wear Models:

In tribochemical wear, material removal occurs due to chemical reactions between the sliding surfaces and the environment, which are facilitated by the mechanical action. Models for tribochemical wear consider the chemistry of the materials and the environment, as well as the mechanical stresses involved.

Each of these models provides a framework for understanding and predicting wear under specific conditions, but they also highlight the complexity of wear processes. The actual wear behaviour of materials often involves a combination of these mechanisms, making accurate prediction challenging. Advanced models and simulations, which can account for the interactions between different wear mechanisms and the influence of complex environmental factors, are continually being developed to improve our understanding and prediction of wear in tribological systems.