In situations where the material composition is unknown you may need help from a metallurgist. Most of the steel supply companies have access to a metallurgist who can advise you or else contact an independent metallurgist. The details they will require of the equipment concerned are its function, duty and conditions in which it operates.

Peter Laczko of Peter Laczko Pty Ltd (ph 9370 5343) offers this advise on selecting material for rollers - "The rollers are best in a pearlitic steel at about 320 to 360 HB hardness. This can be achieved by casting 1050 carbon steel oil quenched and tempered, or by casting in AS 2074 L2B high carbon chrome steel normalised and tempered. If forged steel is used then 1050 carbon steel can be used as above, or 4150 normalised and tempered can be used. If castings are used they must not be welded on the running surface at any stage because uneven wear results in the weld and HAZ (heat affected zone) leaving marks in the tyre and rough rotation of the kiln."

SURFACE LUBRICATION

To help minimise tyre and trunnion wear, dry lubricant blocks rubbing against the tyre can be used. These are available from specialist lubrication companies.

Mike Sondalini - Maintenance Engineer

S T R E S S   I N   M E T A L S   C A U S E   F A I L U R E

ABSTRACT
Stress in metals cause failure. Too much stress in metal will cause it to fail. Failure can occur by putting the metal under a once-only load greater than it can take or by metal fatigue from continually loading the metal cyclically with a high load less than the breaking load. Stress produces strain at the molecular level in the metal and discontinuities between atoms come together to form microscopic cracks. Under continued stress the cracks grow and eventually the metal parts.

Keywords: metallurgy, molecular structure, strain, Hooke's Law, distortion, deformation, dislocation, yield stress, ultimate tensile stress, proof stress, stress reduction, heat treatment, microstructure.

STRESS & STRAIN IN MATERIALS UNDER LOADS

Stress occurs when forces pull (tension), push (compression) or act in combination on a material. When a force is applied the material reacts by distorting to counterbalance the force. A greater force will cause a correspondingly greater distortion until the item breaks.

Stress is the force applied per unit of cross-sectional area square to the force. Its formula is -

Stress (σ) = Force / unit of area

Metric system units are Newton per square meter (N/m^2) and imperial system units are pounds per square inch (psi).

Strain is the amount the material deforms from the unloaded state when the force is applied. Its formula is –

Strain (ξ) = Change in length / original length

Strain has no units, as it is a ratio of length divided by a length. It represents a proportional change in size.

When a force is applied to a metal deformation occurs and it is strained. The more the force - the more the deformation (strain). This relationship is recognised in Hooke's Law and is shown in Figure 1 for two types of metals.

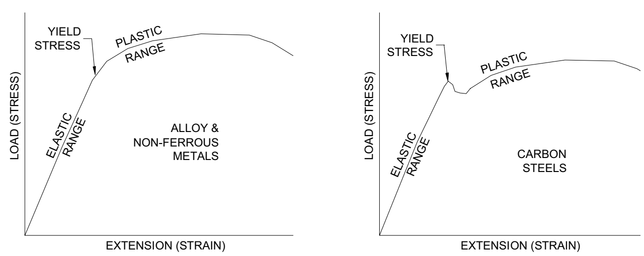

Figure 1. Graphs of Hooke's Law

Figure 1 indicates that metals have an elastic region where load and strain are proportional (a straight line on a graph). In this region the metal acts like a spring and when the load is removed the deformation (strain) reduces and it returns to its original shape. If instead the load increases, the strain (deformation) rises until a point is reached where the metal can no longer sustain the load and it yields. The yielding can be gradual as in the left-hand plot of Figure 1 or it can be sudden as in the right-hand plot.

The aim of much of the work in metallurgy is to discover how to extend the yield point further because in doing so we can fabricate items using thinner metals for less cost.

AT THE MOLECULAR LEVEL

The behaviour of metals under load is a result of their atomic arrangement. When a material is loaded it deforms minutely in reaction to the load. The atoms in the material move closer together in compression and further apart in tension.

Consider the atomic bonds as being springs separating the atoms as shown in Figure 2. The springs are squeezed together in compression and pulled when in tension. The amount an atom moves from its neighbour is its strain. As a force is applied the atoms change a proportionate distance.

This model however, does not explain why there is sudden yielding. With most modern metals yielding usually occurs at about 1% of the theoretic strength of the atomic bonds. Many materials yield at about 0.1% of the theoretic strength.

The reason metals have such low strengths is because of imperfect atomic structures in the crystal lattices which make them up. Often a row of atoms will stop mid crystal and a gap is created in the atomic structure. These gaps act as huge stress raising points known as dislocations.

In the wet corrosion process of Figure 1 the electrons from the corroding anode metal move to the connected cathode where they recombine with the atoms of oxygen and water in the electrolyte to make a new hydroxyl ion (OH^-). This new negatively charged ion then reacts to make a stable compound with the positively charged metal ions (M^{++}) that originally lost the electrons. In this case, the electrons have a continuous pathway to escape the parent metal and the parent metal, which cannot develop a protective barrier, disassociates or falls apart. Once corrosion starts it continues until the ingredients are all used up.

The electrolyte in wet corrosion can be neutral, acidic or alkaline. For corrosion in near neutral solutions (pH 6 – 8) under oxygenated conditions the predominant cathodic reaction is the oxygen absorption reaction ($O_2 + 2H_2O + 4e^- = 4OH^-$) shown in Figure 1. If instead the bimetallic cell has no oxygen present in the electrolyte the hydrogen evolution reaction ($H^+ + e^- = H$ followed by $H + H = H_2$ gas) becomes the cathodic process and the anode continues to corrode. This reaction is a much slower reaction (the H^+ ion has a very low concentration in solution) than the oxygen absorbing reaction. In acidic solutions (pH 0 - 6) the hydrogen ion concentration is higher and the hydrogen evolution reaction is the predominant one. Corrosion rates become extreme as the pH drops (acid gets stronger).

THE ELECTRICAL NATURE OF CORROSION

A flow of electrons means there is an electric current. Wet corrosion produces a corrosion cell. Much like a car battery. The electrons used in creating the corrosion product are continually replaced from the corroding metal. The numbers of electrons available for reacting control the amount of current developed between the two metals. The anode cannot corrode unless there is a cathode. One of them will control the rate of electron flow and thus the corrosion rate.

The intensity (the number of electron and positive ion pairs) is dependent on the potential difference, or voltage, which exists between the metals and the surface area of each metal. Different metal combinations have different voltage potentials between them. Joining two metals with a large potential difference between them produces higher corrosion rates than if the metals were close in electrical potential.

SURFACE AREA EFFECTS

The size of the cathode relative to the anode is important. A large cathode has more surface area through which electrons can flow and so develops an intense electric current with the anode (corroding metal). A small anode connected to it is forced to supply these electrons and will quickly corrode and fall apart. Whereas a large anode connected to a small cathode can provide electrons from any location and will take a long time to show evidence of corrosion.

Where a less noble (base, anodic) metal has to be in contact with a noble metal make sure the less noble metal has at least one hundred times more surface area than the noble metal. Remember – large anode, small cathode – not the opposite.

DIFFERENTIAL AERATION EFFECTS

The corrosion reaction requires oxygen and where oxygen is present the metal is cathodic and where oxygen is depleted the metal is anodic and corrodes. The parts of the metal in contact with the highest oxygen concentration become cathodic and are protected, and the areas where oxygen concentration is low will corrode. Steel posts dug into the ground will rust just below the surface because of this effect.

STAGNATION EFFECTS

During corrosion, ions build up immediately around the anode and cathode saturating their respective regions. The corrosion rate begins to fall due to the concentration of stagnant ions blocking the creation of more ions in the electrolyte. If the ions are removed or more voltage is provided the corrosion rate again picks up. If you want fast corrosion then agitate the electrolyte and add oxygen.

SPECIFIC TYPES OF CORROSION

Corrosion produces physical evidence of its presence. The form it takes depends on the mechanism of the corrosion. Some of the more common forms are explained below.

PITTING CORROSION

A metal can corrode without being in contact with another metal. In this case different areas of the metal take on different electrical potentials. This can occur because of variations in the metal metallurgical properties or because of variations in the surface oxide layer, such as a break, thinning, inclusion like mill scale, contaminant like dirt, etc.

In pitting corrosion the metal at the top of the pit has access to the oxygen in the air and becomes the cathode. At the bottom of the pit oxygen is depleted and the metal becomes the anode. The deeper the pit is the less the oxygen available at the bottom and the corrosion rate increases. Figure 2 shows the mechanism of pitting corrosion.

Reducing wear in abrasive conditions

ABSTRACT

Reducing wear in abrasive conditions. Abrasion is the removal of material from a surface by the movement of material across its surface. The factors affecting abrasive wear are the surface properties of the item being worn away, the abrasive properties of the material moving across the surface and the characteristics of motion. Where abrasive wear is a problem it becomes necessary to understand the mechanism of attrition. Keywords: surface abrasion, size range, particle properties, hardness, abrasion resistant coating, rubber lining.

The following issues affecting the mechanism of abrasion need to be understood.

* The shape of the surface being worn away.
* The shape of the surface or particles doing the abrading.
* The hardness of surfaces and particles.
* The velocity (speed) involved.
* The momentum (a mass moving at a speed) involved.
* The contact time and contact angles during abrasion.
* Contact pressures during abrasion.
* Deformation characteristics of surfaces and particles.
* Chemical and physical properties of surfaces and particles.
* Properties of the components of the surface and particles.
* Particle size range.
* Moisture content effects.
* If the product is in a slurry what is the effect on contact properties due to the presence of the liquid.

All and any of the factors listed play a part in the abrasion process. This provides many opportunities to alter the effect of abrasion by altering the influence of the factors.

SURFACE PROPERTIES

The most important characteristic for a surface to resist abrasion is its hardness. Second to that is its ability to resist surface yielding (indentation). Smooth, flat surfaces are preferred to rough surface finishes.

Hardness results are available for common engineering materials. The hardness test method needs to be appreciated to understand if the hardness being quoted is relevant to your situation. There are three common, but different hardness tests. One lot are those that measure resistance to indentation such as Brinell and Vickers Hardness for metals and Shore Hardness for rubbers or plastics. Other hardness tests measure resistance to scratching (plastic deformation) by objects such as the Bierbaum and Moh tests. The third type of hardness test measures a surface's ability to rebound or its resilience. Rockwell Harness is such a test.

PARTICLE PROPERTIES

The behaviour of particles contacting the surface is as equally important in the abrasion process as the characteristics of the surface. The particles have properties such as harness, surface shape, impact behaviour, size and weight which affect the wear rate. It is useful to get a good appreciation of the characteristics of the particles. Laboratory tests are available but often it is sufficient to get a sample yourself and conduct your own tests.

These 'homemade' tests include -

* determining the density (weight per unit volume),
* looking at the particle's shape under strong magnification,
* feeling (if safe to do so) the particles between your fingers,
* hitting a thin layer of the material with various solid objects (a hammer, piece of plastic, etc) on various surfaces and noting the remains of the particles and how they are imbedded in the surfaces under the sample and in the object,
* gluing some particles onto a wooden board with PVA glue, like making sand paper, and rub various materials across the abrasive surface to observe the effects,
* adding moisture to the particles and repeating the tests,
* inventing your own tests to gain understanding.

Tests lead to a better understanding of what the surfaces and particles will do in the working environment and so permit you to make better material selection issues.

MOTION PROPERTIES

How the surface and particles come together is important to understand. Are the particles being smashed into the surface or are they rolling across it? Are the particles being deflected as they move over the surface or are they moving straight over it? Are the particles heavy and moving at speed or heavy and moving slowly? Is the particle hard and sharp edged and likely to cut like a knife at high velocities? To be able to make a good material selection for abrasive conditions is well worth understanding the forces and motion that the particles will undergo.

Rotating shafts under bending stress.

ABSTRACT
Rotating shafts under bending stress. It is common to transmit motion using rotating shafts. The shafts are mounted in bearings and turned by force through a drive arrangement. The shafts usually also carry a load. These loads cause bending and the shaft reacts by producing counter stresses within itself. Provided the reactive stresses are within the shaft's strength range it will take the load. But if the stresses are greater than what the shaft can take it will bend. Even if the stresses are below the load limit but fluctuate, it is possible that the shaft will break from fatigue. The point of highest stress can be found by looking at the arrangement of the shaft supports and loads and calculating the forces and stresses.
Keywords: Bending moments, tensile stress

If you were to hold a half-full pail of water in your right hand with your arm outstretched your muscles would start to ache. It would not be long before you would have to put it down because of the pain. Your arm was under stress.

Definition of Stress and Strain

Stress is a term used to describe the internal pressure on a material caused by force acting on it. The pain in the muscles of your outstretched right arm was from the internal pressure applied by your muscles.

Strain describes the internal distortion produced by the force. Your muscles contracting against the force of the half-full pail of water were straining to keep the load up. Where there is a force there will also be stress and strain together.

Bending Stress in Machinery Shafts

Figure No. 1 shows three common situations of loaded round, rotating shafts. On the left-hand side is a cantilevered load such as the drive pulley on an electric motor. In the center is a uniform load such as on the head and tail pulleys of a conveyor. To the right is a point load such as occurs on the shafts carrying the gears in a gearbox.

The term 'simply supported' just means the shaft is held up at the two ends so that both ends are able to move and curve with the effect of the load. If one end could not bow with the load, such as if the shaft was in a journal bearing and not a roller bearing, the term to use would be 'restrained end-supported' load. In this case the shaft could not start to bend until it was clear of the restraining journal and the resulting stresses would be in different positions along the shaft.

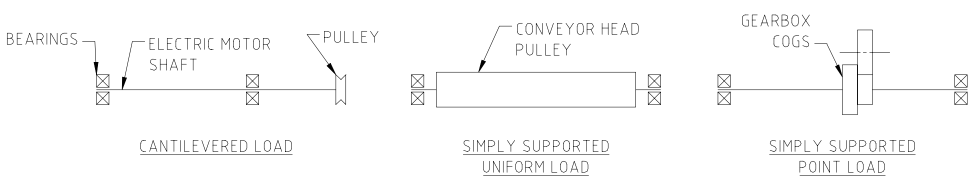

Figure No. 1. Typical Situations of Shafts under Load.

Each of the shafts can be analysed and the stresses calculated. The highest stress is then checked against the allowable yield stress before it bends (See article 233 'Stress in Metals) and the fatigue limits of the shaft material (See article 283 'Metal Fatigue Failure'). The analysis determines if the shaft will meet its duty, or if a different size shaft or a different material with greater stress carrying ability, is needed from that originally proposed.

The point of highest stress is found by drawing a bending moment diagram for the shaft. This is a graph showing the force multiplied by the distance along the shaft from a start point (datum). The size of the bending moment depends on the amount of load and the distance it acts from the datum. A load acting a long way from the datum produces bigger bending moments in the shaft than one acting closer to the datum. Figure No. 2 shows bending moment diagrams for each of the three load conditions of Figure No. 1.

Look for the Point of Greatest Stress.

For single diameter shafts the location of the highest bending moment is also the point of highest stress. If the shaft is stepped with different diameters it is necessary to calculate the maximum stress along each diameter. The stress in a particular spot on a shaft depends on the shaft's ability to carry the moment. For a round shaft that ability depends on the area available to take the load and the strength of the shaft material.

The ability to resist breakage depends on the shape and size of the shaft (Second Moment of Area) and the ability of the material to resist tearing apart (Young's Modulus). If the shaft thickness is too little, or the shaft material is too weak, the shaft will bend or snap. Knowing the location of the maximum stress allows one to locate the point of likely failure in overload situations and to prevent them arising.

Bending moments also cause deflections. The shaft bends under the combined effect of the loads. In simply supported situations the maximum deflection is at the point of maximum bending moment. This is also the point of maximum stress. By