Failure Analysis

Vibration Analysis

Tells us something is going on that is out of the ordinary
If interpreted properly can suggest what components are showing signs of failure

Oil Analysis

Tells us what is floating around or is suspended in the oil.

Gear Failure Analysis

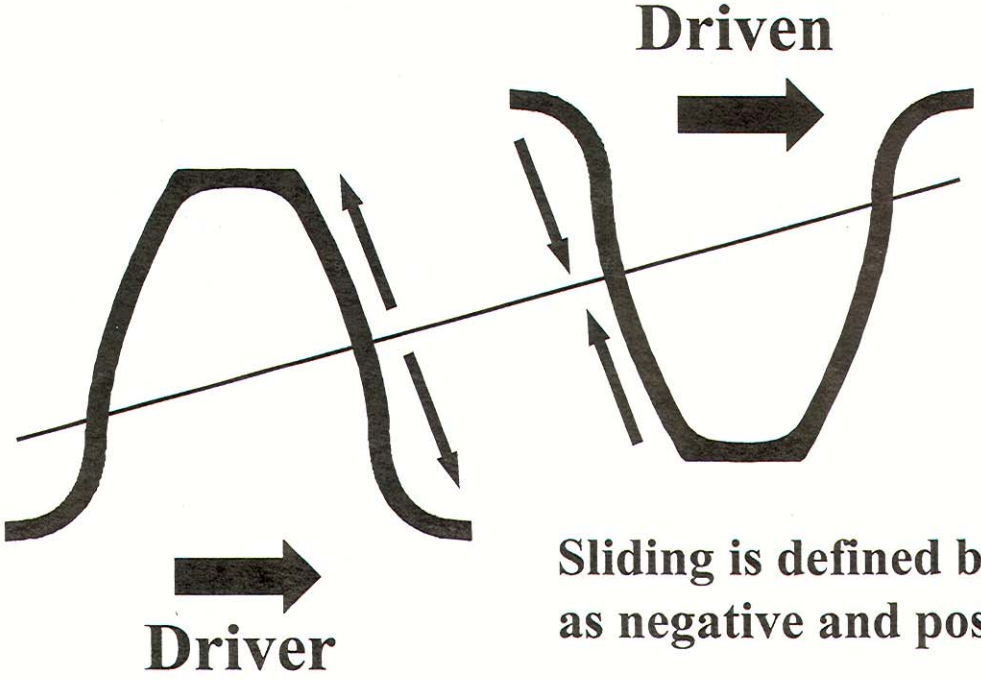
The Teeth Tell The Story!!!

Failure Analysis - The Teeth Tell The Story

A Refresher on Gear Action Part I:

Gears only roll at the pitch line
Sliding action occurs above and below the pitch line

Sliding Action of Gear Teeth



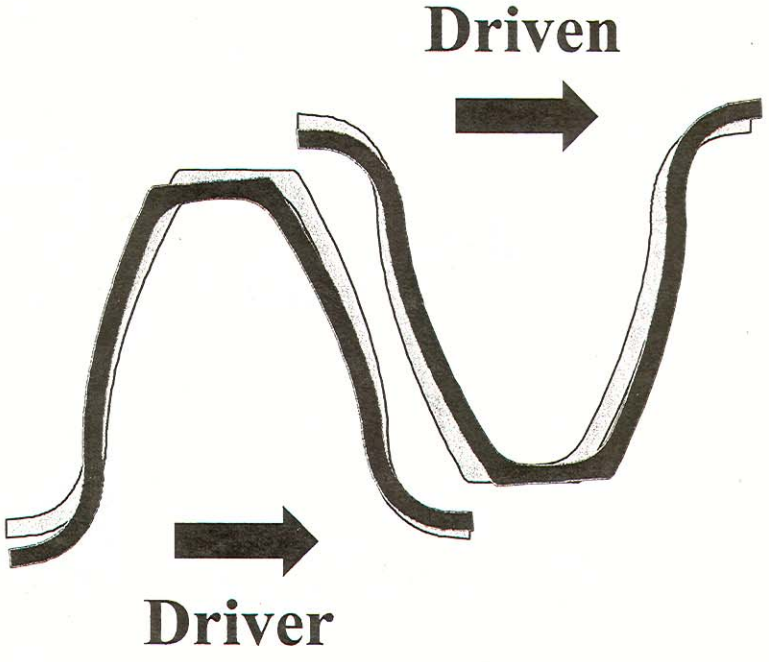
Sliding is defined both as negative and positive

Failure Analysis - The Teeth Tell The Story

A Refresher on Gear Action Part II

Gear teeth flex as they cycle in and out of mesh

Flexing Action Of Gear Teeth

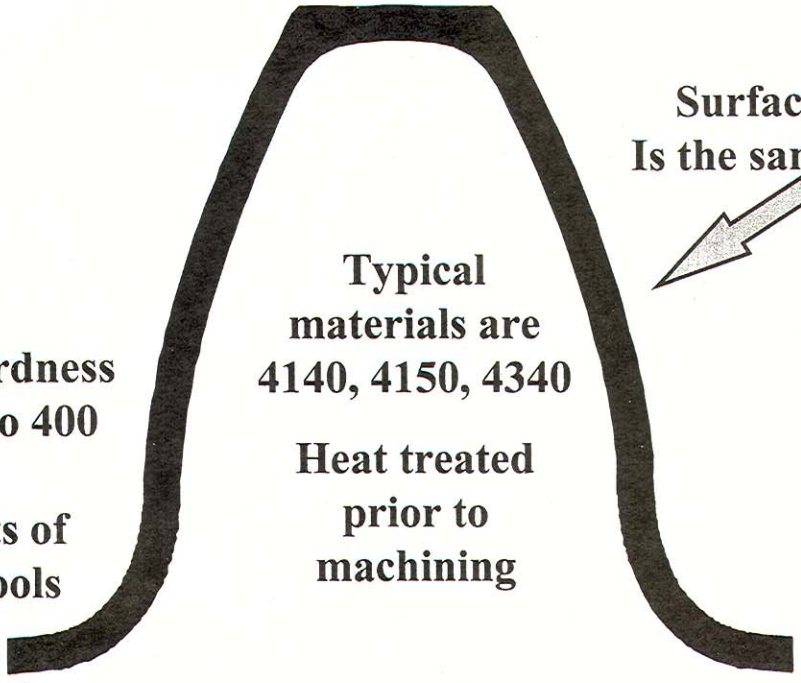


Gear Hardening

Thru Hardened 380 / 420 Bhn

A heat treating process to hardness levels up to the limits of most machine tools

Through Hardened Gear



Surface Hardness Is the same as the core

Typical materials are 4140, 4150, 4340

Heat treated prior to machining

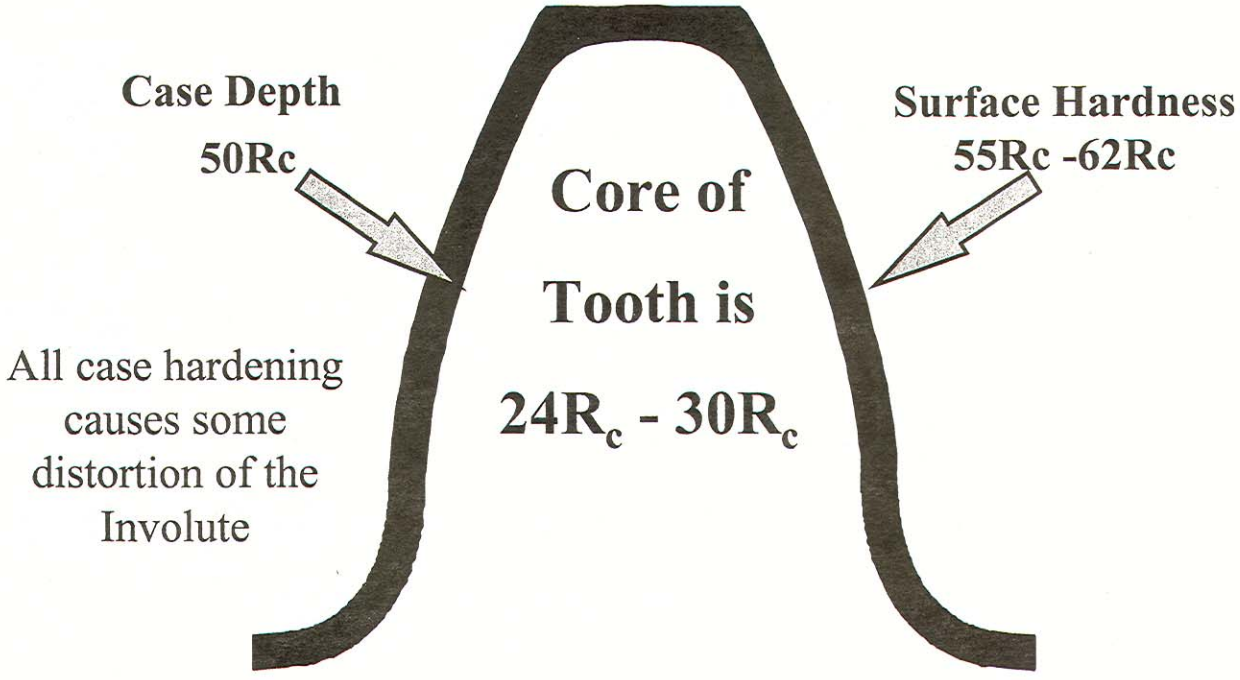
Generally hardness range is up to 400 BHN at the limits of machine tools

Gear Hardening

Case hardened surface which can be 60 + RC with a ductile core

We case harden to increase durability (pitting resistance)
A finishing process is usually required because of distortion after heat treating

Case Hardened Gear

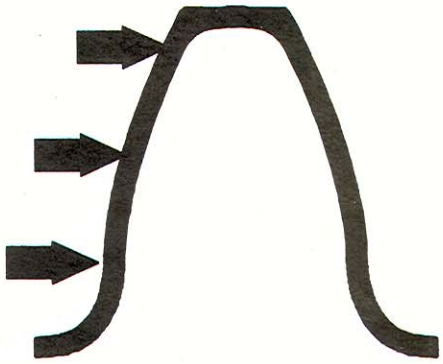


What is Failure ?

It is argued one observers failure is another observers wearing in

Application and time of progression dictates how serious the problem

The Involute Profile and Failure

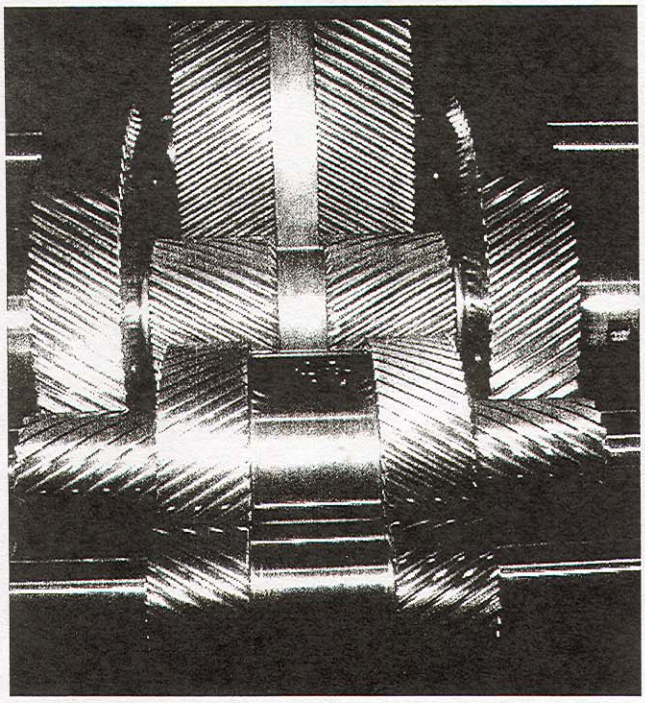


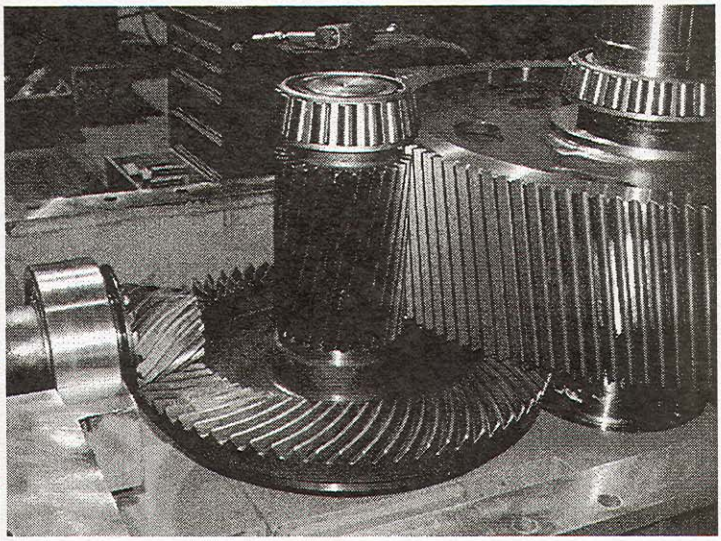
Involute profile

Any change to the involute or contact surface occurring during operation can be described as a beginning failure mode

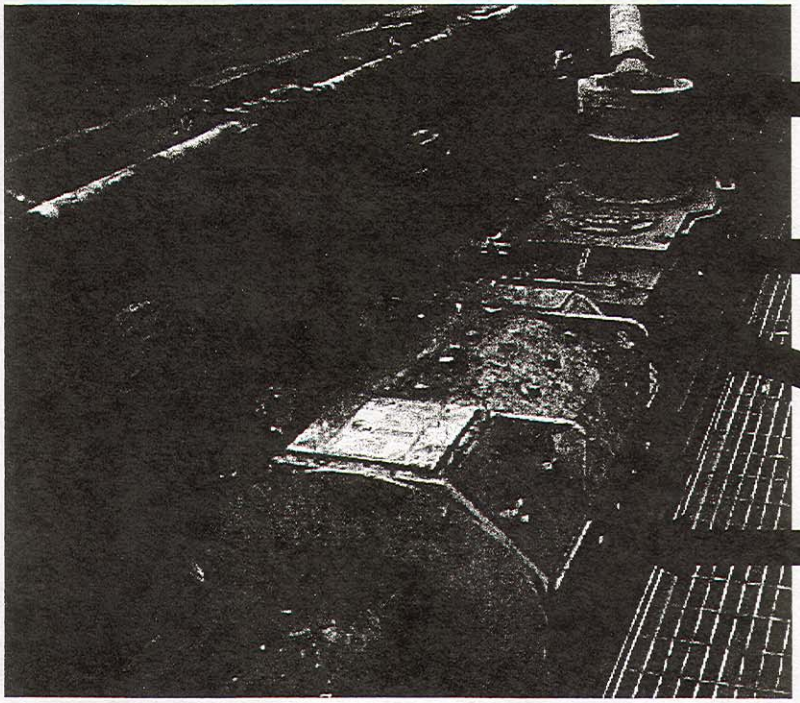
Components

Gears and Bearings





The System



Simplistic Approach Part I

Is it a lubrication problem ?

Is it a material problem ?

Simplistic Approach Part II

Is it a system problem?

Is it a component Problem?

What caused the problem?

How do we fix the problem?

www.pragergear.com

Ratings Are Crucial

Each gear set is rated independently

Gear Box manufacturers do not use the same strength and durability formulas

Economics plays a tremendous role in mechanical size

The gear box is limited by the weakest set

Usually that is the low speed gear set

Although the gears may be designed for enough rating, often shafts deflect under load

Causes - Manufacturing Errors

Processing & controls

Assembly

Inspection & Testing

Gear Failure Analysis - the Process

Review the documentary evidence

Review service history

Interview witnesses

Visually examine

Review geometry & design

Perform appropriate tests

Evaluate all data

Implement corrective actions

Don't do it again!

Root Cause Failure Analysis…

Become an Equipment Reliability Detective:
Preserve Failure Data

Reliability Magazine, November 1994

www.Maintenanceresources.com/ReferenceLibrary/Failure Analysis/Become.htm

Treat failure like a homicide and freeze the scene

Take photographs of everything before anything is disturbed.

Bag and tag any items which may yield information (murder weapon, hair, clothing, fibers, etc).

Dust for fingerprints.

Interview people (neighbors, friends, colleagues etc.).

Map the position of the body relative to its surroundings.

Review available documents.

Parts

Any failed components such as bearings, seals , shafts, valves, nozzles, lubricants, chemicals from spills, and gases from leaks.

Position

Where were things at the time of failure? Was the valve open or closed? What are the instrument's settings? Position of parts?

Paper

Operating conditions prior to, during, and after the incident (temperature, pressures, levels, etc.), vibration monitoring results, equipment histories, operation procedures, manufacturing procedures and equipment specifications.

People

Who are they, and what did they see, hear, feel or smell prior to, during, and after the incident? Was anything unusual being done around the time of failure? What was their perception of the sequence of events?

Paradigms

What are the cultural norms of the organization? What do people accept as a way of doing business, such as communication between units or shifts? What repetitive remarks were made during the interview that indicate beliefs, values or deep-seated convictions?

Richard's Rule of Gear Failure:

Good Gears

Don't Fail if they are

Big Enough and

Kept Slick Enough !

Gear Failure Analysis …the Method

Identify *Class*

Determine *Cause*

Apply *Remedy*

The problem is none of these failures occur as isolated events!

It is usually a combination of events that lead to a gear failure!

The trick is to determine what occurred first!

Common Sense

Notice the remedies for wear *usually* involve lubrication

Notice when we talk about contact fatigue, plastic flow, and breakage, remedies *usually* involve the base material

Gear Failure Class - Wear

Premature wear is usually associated with a failure of the lubrication system, not necessarily a failure of the lubricant" !

"Mineral based oils loose their protective qualities around 180 Degrees F !"

"More accurate gearing assures more accurate distribution of the lubricating film!"

"Long term wear usually occurs because of a lubrication failure which later leads to a metal failure!"

Basic Wear Remedies

Do those things that allow the lubricant to do what it is supposed to do!

Filters & Pumps
Improves Gear Finish
Improve Gear Quality

Gear Failure Class - Contact Fatigue

"The degradation of gear tooth surfaces due to the inability of their material to carry the applied loads."

"The durability rating of a gear set relates to its resistance to pitting."

"The strength rating of a gear set relates to its resistance to breakage"

Gear Failure Class - Contact Fatigue

Pit - *"The detachment of material fragments from the surface of mating gear teeth because of repeated contact stress - hertzian fatigue."*

"Pits can cause cracks, cracks cause wrecks!"

If you have pits, or any crater on a tooth surface, you are eventually going to develop a crack!

The problem is no one can say when or how fast it will propagate!

It's a function of cycles!

Contact Fatigue Remedies

Improve Gear Contact Mesh

Correct Gear Alignment

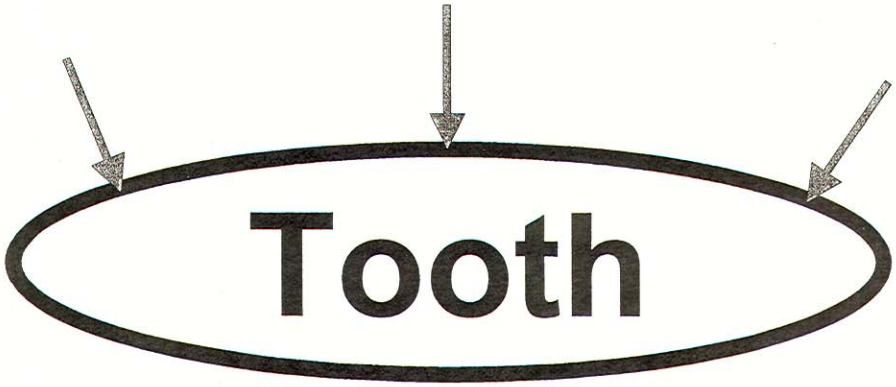
Increase Gear Surface Hardness

Improved Gear Materials

Geometric Design Alterations

Crowning

Direction of Loading



.005 Crown

Why Teeth Break

They wear so thin they cannot support the load

They are overloaded beyond their strength and durability ratings sometimes locally due to misalignment and sometimes immediately due to shock

Mistakes are made in material selection, manufacturing, and design

Materials sometimes contain flaws

Something exists that causes a crack to propagate

They are subjected to so many bending cycles that they simply break out