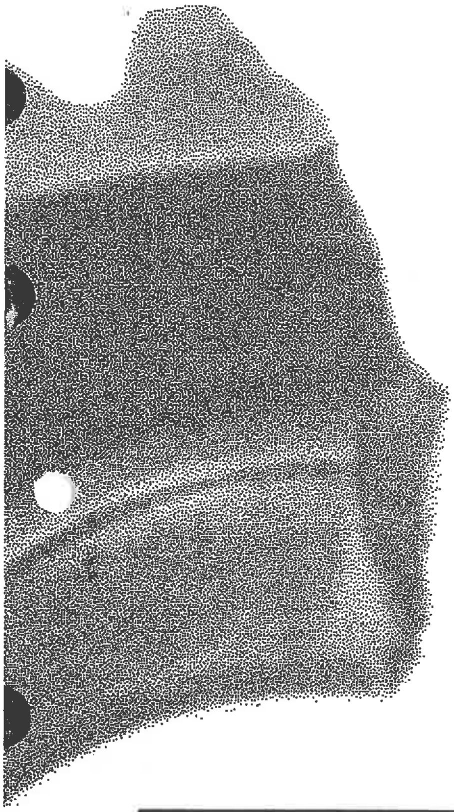
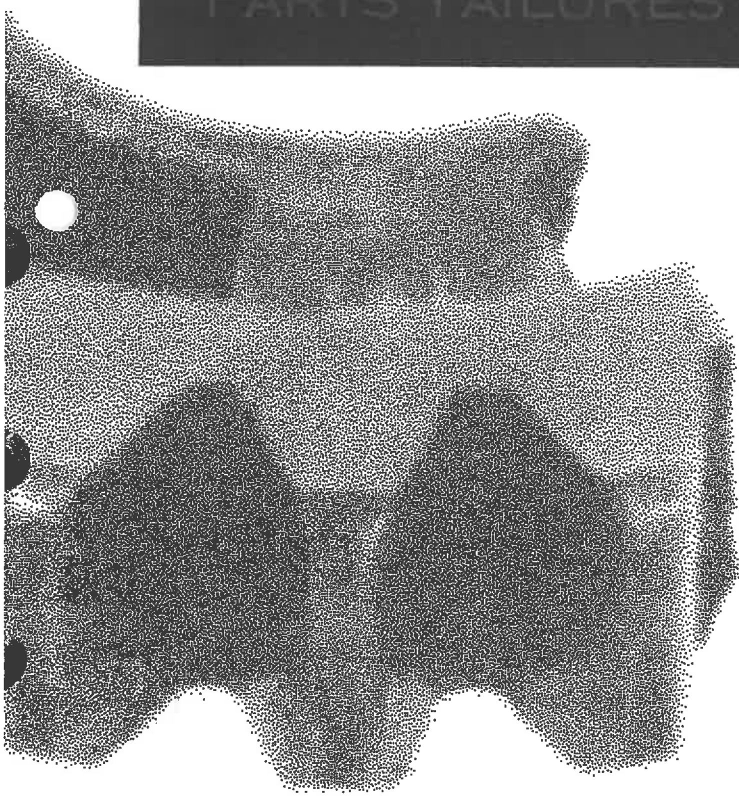
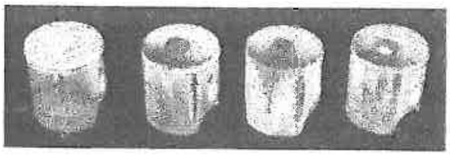
YAMAHA



PARTS FAILURES IDENTIFICATION GUIDE





LIT-11661-00-PF

TO THE READER

This manual illustrates many examples of failed parts. Explanations and possible reasons for failures are included with each picture. These failure causes are **not necessarily the only conditions that could cause the part failure.** Make sure to consider all factors concerning the operation and maintenance of the machine when analyzing failures.

Most of the failures shown are secondary failures. Some other problem may have caused the pictured failures. **Be sure to find the original problem area when diagnosing any failed part.**

Remember, this manual cannot identify all causes of failed parts.

ACKNOWLEDGEMENTS

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Pages: 1~8, 15~26, 29~43, 47~51, 55~70

CONTENTS

PISTONS, RINGS, CYLINDERS
Introduction 1
Identifying Piston Failures 1
  Detonation 1
  Preignition 2
  Scuffing & Scoring 3
Identifying Ring Failures 4
  Wear 4
  Chipping 5
  Scuffing & Scoring 5
  Breakage 6
  Sticking 6
Identifying Cylinder Failures 7
  Wear 7
  Chemical Attack 7
  Scratching 8
Miscellaneous Failures - Pistons, Rings, Cylinders 9

JOURNAL BEARINGS
Introduction 15
Journal Bearings
  Dirt 15
  Lack of Lubrication 16
  Misalignment 18
  Overloading 19
  Corrosion 20

VALVE GEAR TRAIN
Introduction 21
Identifying Valve Failures 21
  Distortion of Valve Seat 21
  Deposits on Valves 22
  Too Little Tappet Clearance 23
  Burned Valve 23
  Erosion 24
  Heat Fatigue 24
  Pitting 24
  Breaks 25
  Wear 26
Miscellaneous Failures - Valve Gear Train 27
  Dislodged Valve Seat 27
  Valve Cupping 27
  Worn Rocker Arm 27
  Worn Camshaft 28

GEARS & RELATED PARTS FAILURES
Introduction 29
Gear Terminology 29
General Categories of Failures 30
  Wear 30
  Pitting, Spalling, Case Crushing 32
  Fatigue 35
  Impact 38
  Rippling, Ridging, Cold Crushing 38
  Combined Effects 40
Specific Categories of Failures 41
  Ring Gear Teeth 41
  Ring Gear & Drive Pinion 42
  Drive Pinion 42
  Transmission Countershafts 43
Miscellaneous Failures - Gears & Related Parts 44
  Broken Gear Tooth 44
  Broken Gear 44
  Rounded Gear Engagement Dogs 44
  Shift Forks 45
  Shift Shafts 45

SHAFTS, CRANKSHAFTS, CONNECTING RODS, AXLES, UNIVERSAL JOINTS
Introduction 47
General Failures 47
  Overload 47
  Torsional Fatigue 48
  Severe Service 48
  Impact Failure 49
  Transmission Shafts 50
  Spindles 50
Universal Joint (U-Joint) Failures 51
  Fatigue 51
  Broken Journal 51
Miscellaneous Failures - Shafts, Axles, Connecting Rods 52
  Universal Drive Axle 52
  Drive Shaft 52
  Broken Connecting Rod 53
  Big End Conn. Rod Bearing Failure 53
  Small End Conn. Rod Bearing Surface Failure 53
  Crankshaft Thread Damage 54

ANTI-FRICTION BEARINGS
Introduction 55
  Contamination 55
  Improper Lubrication 57
  Improper Installation 59
  Careless Handling 61
  Misalignment 64
  Severe Service 64
  Vibration 65

BOLT & NUT FAILURE DURING ASSEMBLY
  Bolt Twist-off 67
  Galling of Threads 67
  Yield & Tension Failure 67
  Fatigue 68
  Loss of Torque After Assembly 68
  Galling of Mating Parts 69
  Shear Failure 69
  Nut/Bolt Failure 70
  Nut Dilation 70

PISTONS, RINGS, CYLINDER LINERS

INTRODUCTION

Pistons, piston rings, and cylinders are an essential part of an engine:

- Pistons receive and transmit the force of combustion to the crankshaft
- Cylinders guide the piston
- Piston rings form a gas-tight seal between the piston and the cylinder.

IDENTIFYING PISTON FAILURES

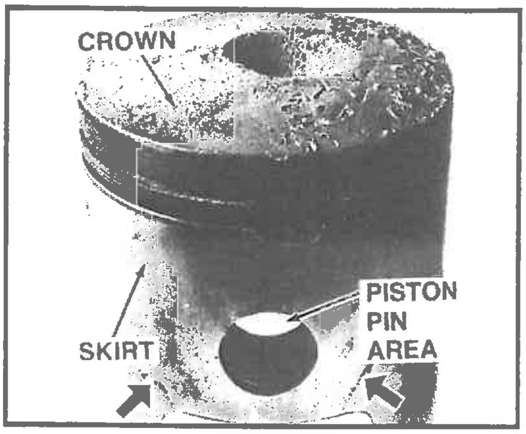
The principal causes of piston failures in gasoline engines are:

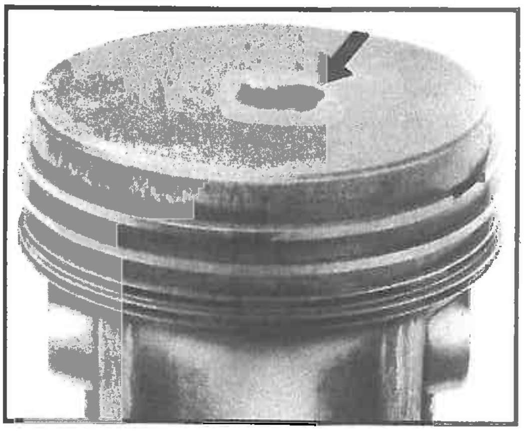
- Detonation
- Preignition
- Lack of lubrication
- Corrosive wear
- Physical damage to pistons
- Dirt ingestion

Detonation

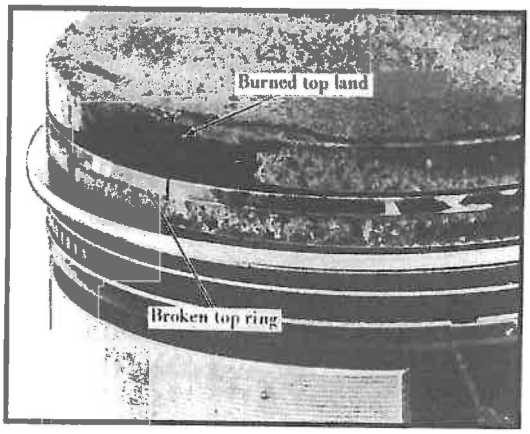
Detonation is uncontrolled combustion accompanied by a loss of power and waste of energy. The piston is frequently damaged.

These pistons have been damaged by detonation. Because of the hammering pressures, piston damage usually appears as fractures on or through the crown, or in the skirt and piston pin area (large arrows).



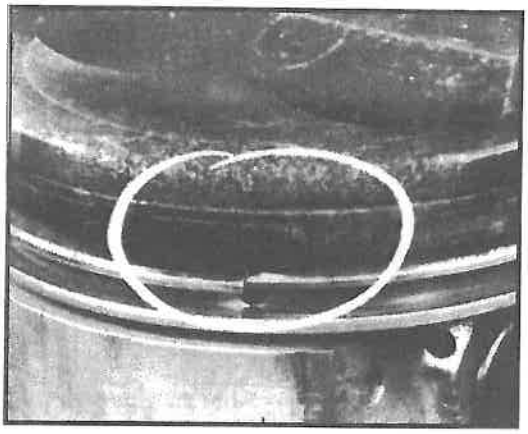


A noticeable knocking occurs when fuel in the cylinder ignites too early, too rapidly, or unevenly. The resulting "knock" can burn the piston, wear out the top groove, or cause the ring to break or stick.



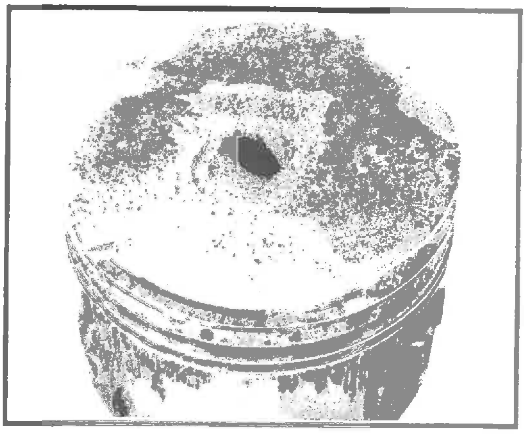
Causes of combustion knock:

- Lean fuel mixtures
- Fuel octane too low
- Ignition timing advanced too much.
- Lugging the engine or excessive fuel in the combustion chamber
- Cooling system not working (overheating)



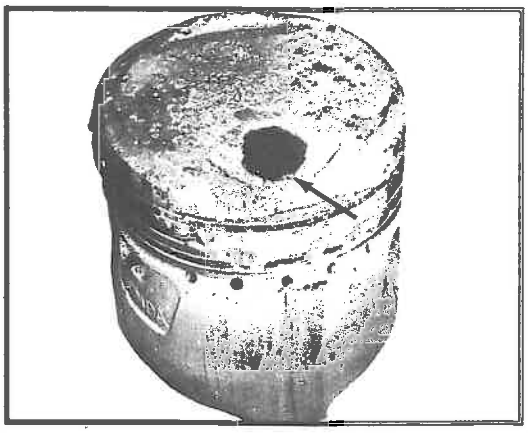
Preignition

Occurs when the fuel ignites before the spark occurs. As a result, part of the fuel burns while the piston is still coming up on its compression stroke. **The burning fuel is compressed and overheated by the piston, and by further combustion.** The heat can be so intense that engine parts melt.



These pistons were damaged by the heat of preignition. The intense heat of preignition burned and melted the piston. Damage may appear on and through the crown, through the ring lands, or both. Damage usually looks like a blow torch has been held against the piston crown, melting or bubbling it.

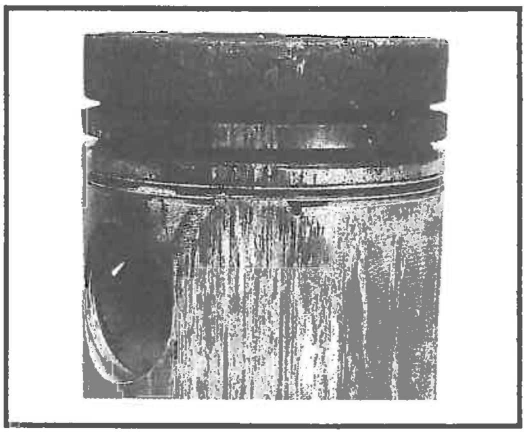
Causes of Preignition:



- Carbon deposits that remain hot enough to ignite fuel early
- Overheating
- Valve operating too hot because of excessive guide clearance, bad seats, or improper adjustment
- Hot spots caused by damaged rings
- Spark plugs are wrong heat range
- A loose spark plug
- Head gasket material sticking out into the combustion chamber
- Dings in combustion chamber which stick out causing a hot spot

Scuffing and Scoring

Scuffing and scoring (adhesive wear) is caused by too much heat. When two metal parts rub and the heat builds up to the welding point, a small deposit or "hot spot" of metal is pulled out and deposited on the cooler surface.



Scuffing leaves discolored areas on the surface of rings, pistons, and cylinder walls. Scuffing starts as tiny surface disturbances. If these are not removed, scuffing spreads and becomes noticeable and more severe. It is then called scoring. Any engine condition which heats rubbing parts to the welding point, or which prevents the transfer of heat from these surfaces, influences scuffing.

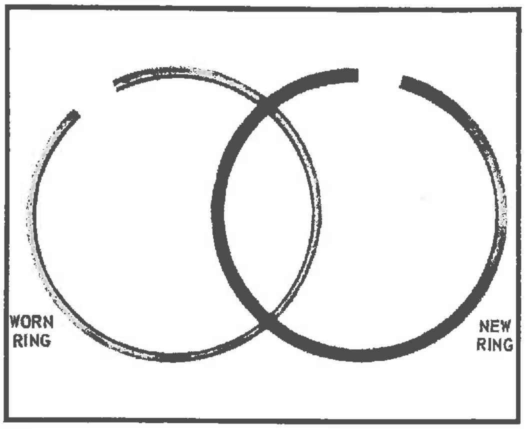
The following are possible causes of scuffing and scoring:

- Improper warm-up
- Lubricating system not functioning/Lack of oil in gasoline - premix engines
- Cooling system plugged
- Detonation and preignition
- Lugging or overloading

IDENTIFYING RING FAILURES

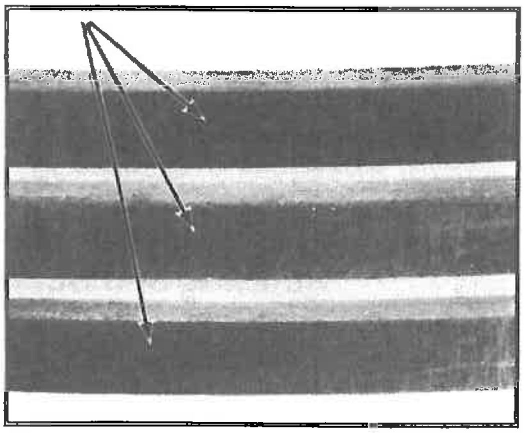
Wear

Badly worn compression ring is shown at left. A new ring is at right. The worn ring is thinner then the new ring.

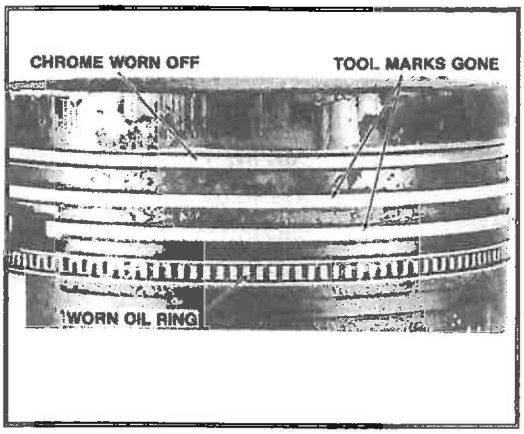


Vertical scratches across the faces of rings are caused by airborne abrasives (such as sand), or abrasives left in the engine at the time of overhaul.

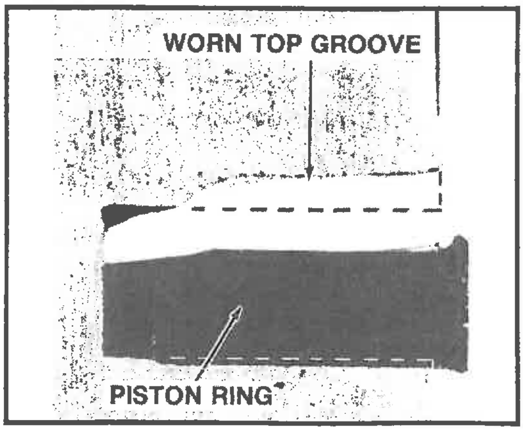
Unless the source of the abrasives is found and corrected, the life of any new ring set will be short.



This shows rails of the oil ring worn down to the steel expander spacer as well as substantial wear to the spacer. The spacer can wear in this manner only from cylinder wall contact. An oil ring worn in this manner can no longer provide oil control.

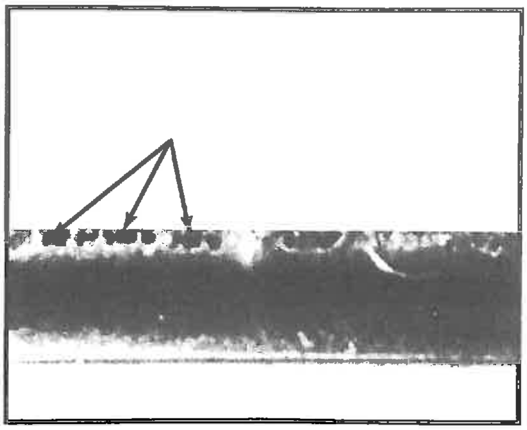


Many aluminum pistons removed for re-ring installation have excessively worn top grooves. This area wears most because it is exposed to maximum combustion heat and pressure and all airborne abrasives that enter the engine. Check for this condition before reusing a piston. See Service Manual for specification.



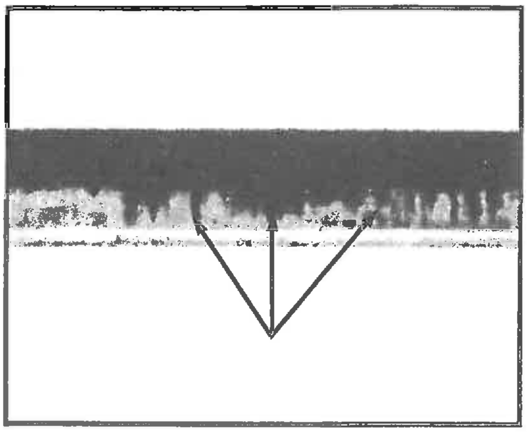
Chipping

Chrome can be chipped from rings by careless handling or use of incorrect ring compressors. Rings can also be chipped during operation by incomplete combustion.



Scuffing and Scoring

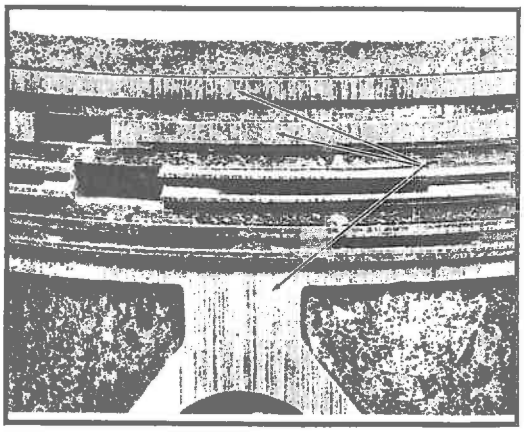
Ring scuffing resembles piston scuffing. Small amounts of ring material have pulled away and stuck to the liner.



Causes of scuffing and scoring are:

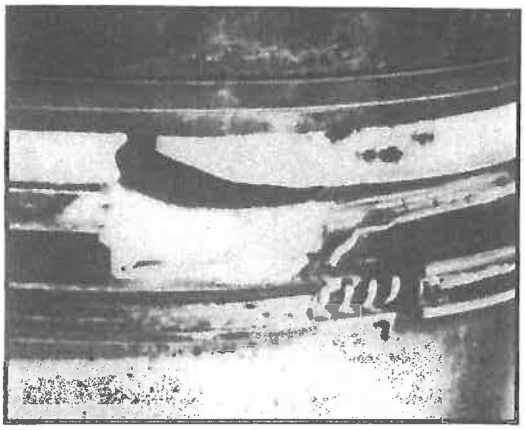
- Overheating due to a faulty cooling system
- Lack of cylinder lubrication
- Improper combustion
- Incorrect or insufficient bearing or piston clearances
- Improper break-in
- Coolant leakage into cylinder
- Too much fuel in combustion chamber

Scoring is a more severe form of scuffing. Both the rings and the piston are scored. When metal-to-metal contact occurs between the two running surfaces and the temperature of one of these surfaces reaches the welding point of the material, scoring will result.



Breakage

When a ring breaks, the pieces bounce around in the groove causing severe erosion of the land and some scuffing on the piston crown or skirt. A broken ring caused erosion of second and third lands which look "melted" away.

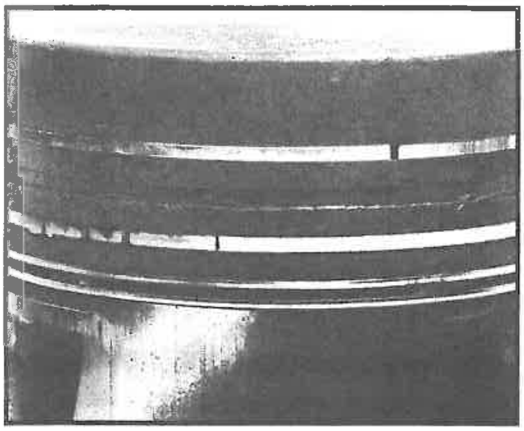


One of the major causes of ring breakage is incorrect installation. Ring breakage also occurs when the groove has worn too wide or is filled with carbon.

On two-stroke engines, ring breakage can be caused by the ring catching in a port, rotation due to wear, or ring locator pin failure.

Sticking

Deposits caused by too much heat, unburned fuel, poor quality fuel, and excess lubricating oils collect in the piston ring area. Ring failure usually occurs when these deposits harden and stick the rings in their grooves.



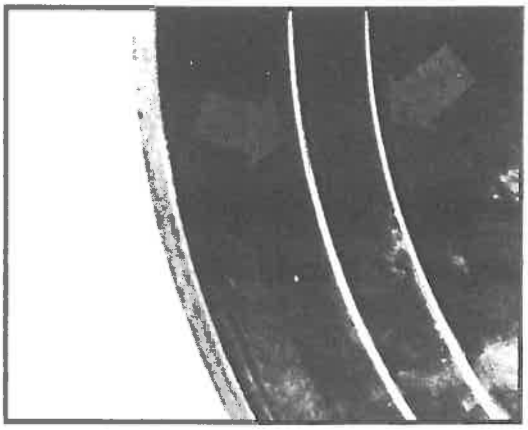
When the rings are completely stuck they often break.

Deposits on the top ring groove cause sticking, scuffing, and scoring because they keep out oil and trap metal particles that wear off the piston.

IDENTIFYING CYLINDER FAILURES

Wear

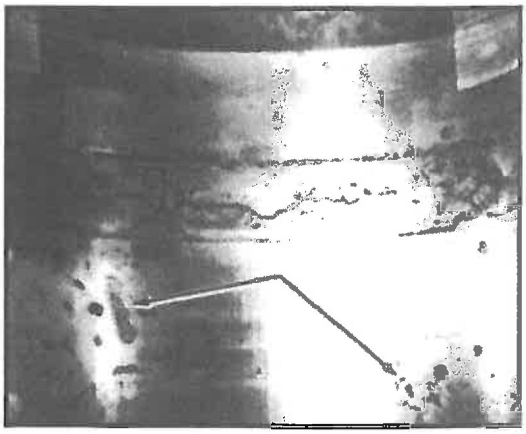
Wear steps are often visible in used liners. Normally, the cylinder should be replaced if this wear is present. Cylinder liners are not available separately. If clearance between piston and cylinder liner is within service specification, and if liner is not otherwise damaged, the cylinder may be reusable.

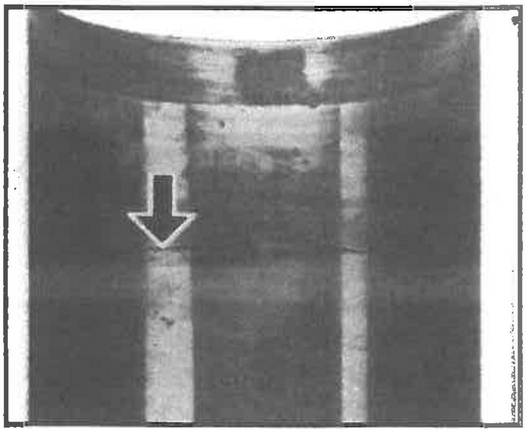


Chemical Attack

Distinct etch marks (corrosion) in the ring travel area of the wear surface are visible. This is the result of the corrosive action of the coolant. The piston usually is scored before the corrosion appears.

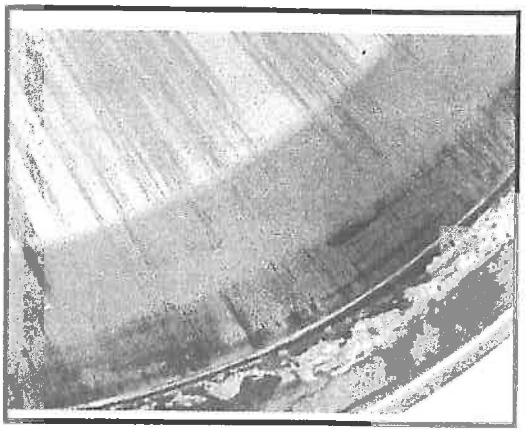
This apparent crack is actually a line caused by chemical attack.





Scratching

Scratching occurs when dirt particles enter the engine. During operation the dirt moves between the liner and piston rings causing scratches. This is usually caused by poor or incorrect air filter maintenance or loose or damaged intake tract connections.

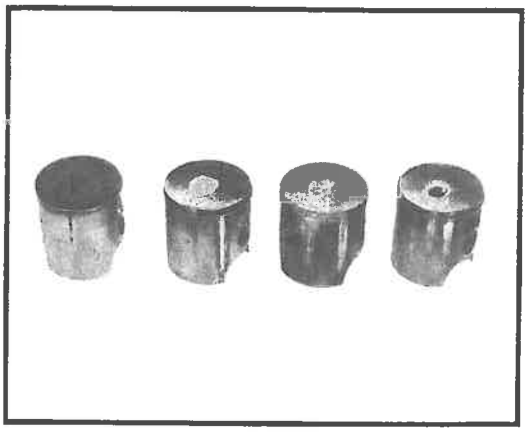


MISCELLANEOUS FAILURES — PISTONS, RINGS, CYLINDERS

Overheating

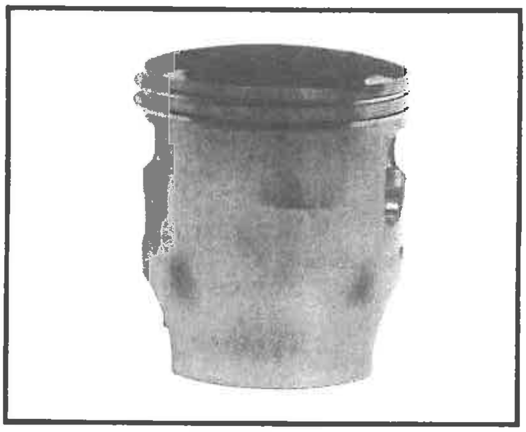
These photos show overheating and melting of the piston crown. This type of failure can usually be attributed to preignition caused by:

- Ignition timing too far advanced
- Air leak at the intake tract of the engine
- Carburetor jetting too lean



Vertical Scratches

This shows vertical scratches on the piston with no seizure marks. The aluminum is a dull color. This type of damage is usually caused by ingestion of foreign material such as dirt or sand because of poor intake air filtration.

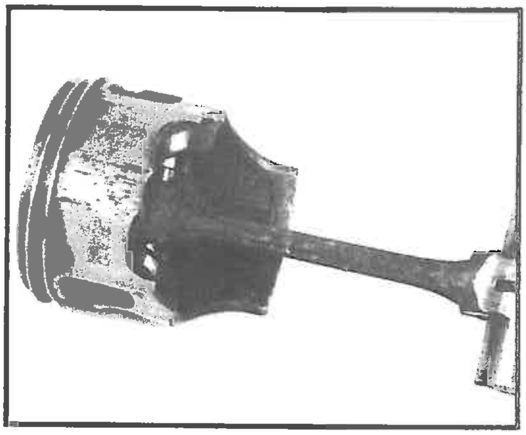


Broken Piston

This shows breakage of the piston intake skirt.

These failures can be caused by excessive clearance between the piston and the cylinder allowing the piston to rock back and forth in the cylinder. Possible causes are:

- Ingestion of foreign objects or material, (dirt, sand, or water)
- Improperly bored cylinder
- Piston worn too much and should have been replaced earlier



Erosion

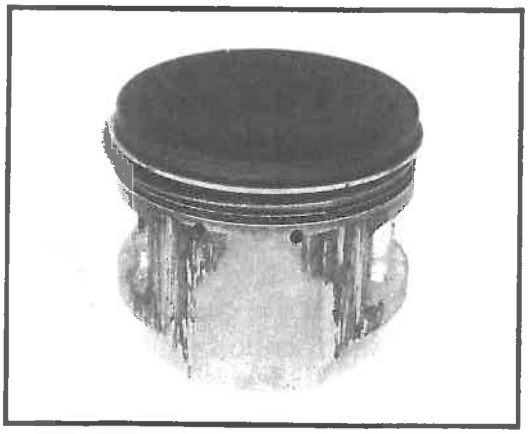
This shows excessive piston erosion on the exhaust side. This can usually be attributed to:

- Lean carburetion
- Engine sucking in air (air leak)
- Timing too far advanced

Seized Piston (seize marks on exhaust side and ring land eroded away)

This shows heavy seize marks on the exhaust side and badly eroded ring lands. This is usually caused by:

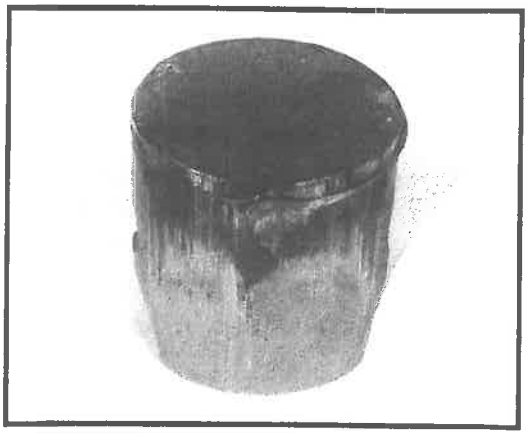
- Lean carburetion
- Engine sucking air (air leak)
- Timing too far advanced



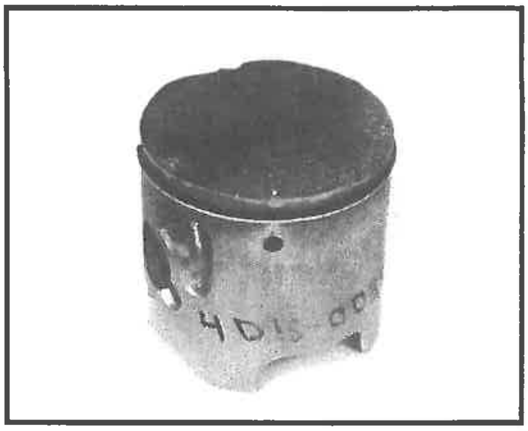
4-stroke Piston Seizure

This shows piston seizure on a 4-stroke engine. This failure is usually caused by the piston overheating because of:

- Blocked cooling fins or cooling system failure
- Carburetor jetting too lean
- Ignition timing too far advanced
- Lubrication system failure



Ring End Catching Exhaust Port (2-stroke Engine)



This shows the piston ring end has caught in the exhaust port damaging the piston and almost always the cylinder.

This type of failure is usually caused by the piston ring locating pin dislodging and allowing the ring to rotate. The dislodging of the locating pin can be caused by sustained high RPM operation.

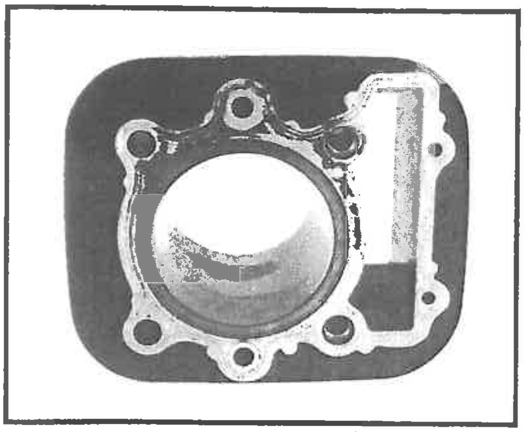
Ring(s) can also rotate because of excessive wear or detonation causing the ring groove to get wider.

Scuffing And/or Seize Marks

Exhaust Port Side

This shows scuffing or seize marks on the exhaust side of the cylinder wall.

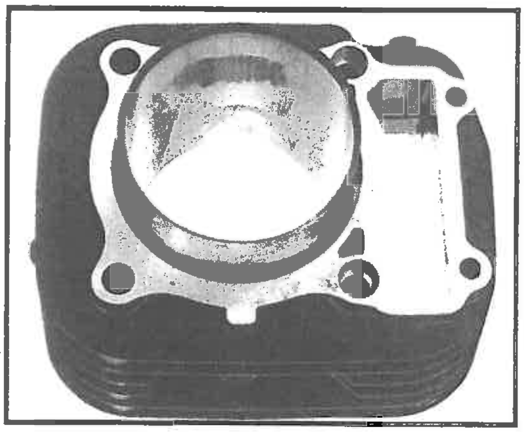
This type of failure is most likely caused by overheating from blocked cooling fins or insufficient piston to cylinder clearance.



Intake Side

This shows scuffing or seizure marks on the intake side of the cylinder wall.

These failures are usually caused by lack of lubrication from oil pump failure, blocked or diverted oil pump passage.



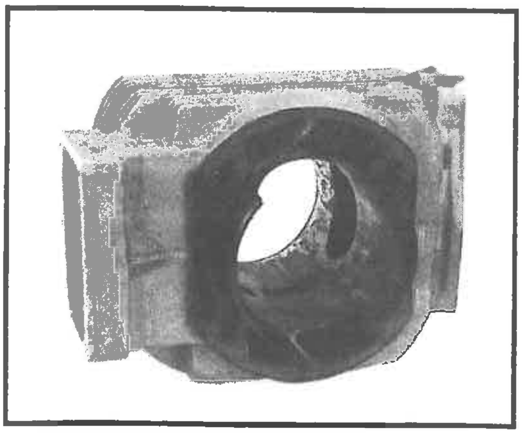
Overheating

This shows signs of overheating. Cylinder is very dry and aluminum from the piston is seized into the cylinder wall.

These failures are caused by:

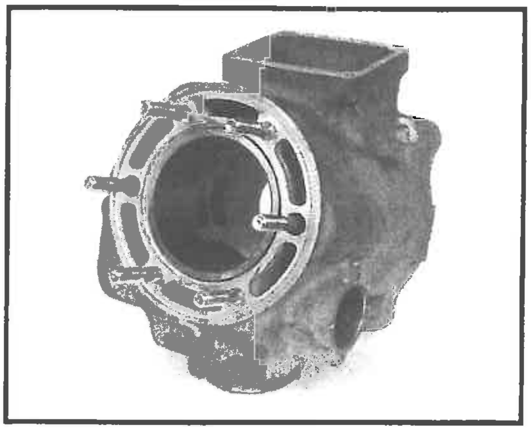
Lack of oil - oil pump failure

Cooling system failure



Nicasil Damage

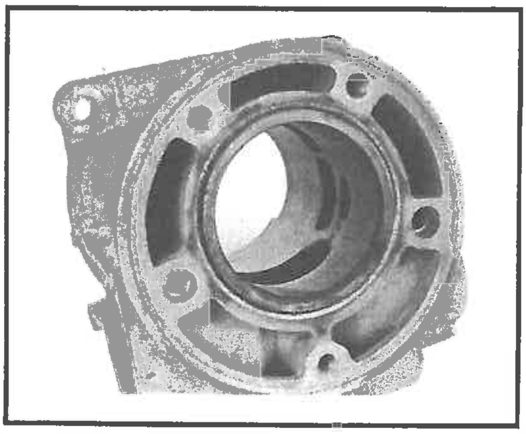
This shows Nicasil plating that is peeling from the cylinder wall. This is usually caused by:



- Improper chamfering of the cylinder ports
- Improper process of Nicasil plating
- Plating may also be damaged at the top edge near the cylinder head gasket by detonation or cooling system failure.
- Heavy seizure

Gouged Cylinder Wall

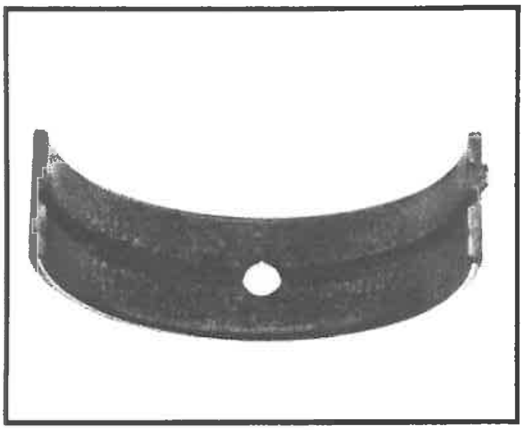
This shows a deep gouge or scratch in the cylinder wall near the transfer port. This type of failure is usually caused by an improperly installed piston pin retaining circlip.



INTRODUCTION

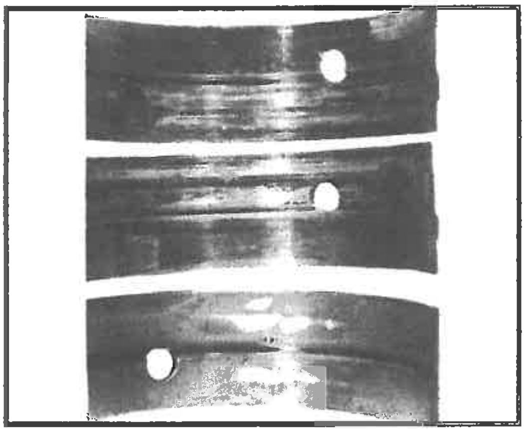
When replacing damaged bearings it is vital to determine the cause to prevent repeated failure. Most failures are can be attributed to the following causes:

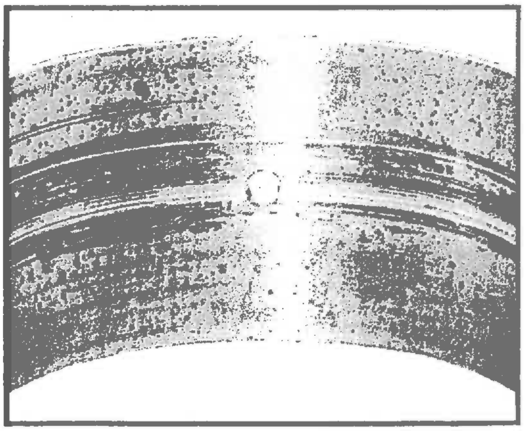
- Dirt
- Lack of lubrication
- Improper assembly
- Misalignment
- Overloading
- Corrosion



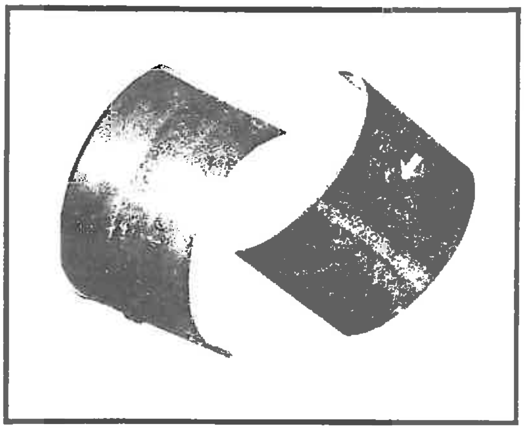
Dirt

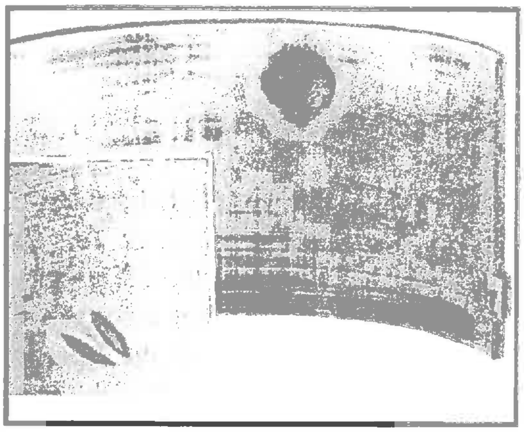
Large dirt particles can embed in the soft bearing material. This causes wear and decreases the life of both the bearing and its journal. **Dirt is the most frequent cause of bearing failure.** Prevent this by cleaning the area surrounding the bearing thoroughly during installation and by proper maintenance of any air and oil filters.





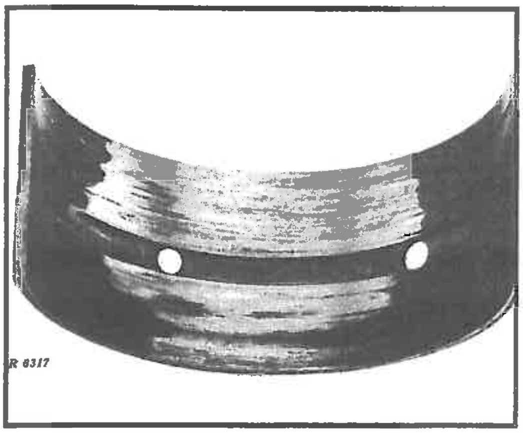
These show when a particle of dirt was left during bearing installation; it caused damage by pushing the bearing inward increasing localized pressure and heat.





Lack of Lubrication

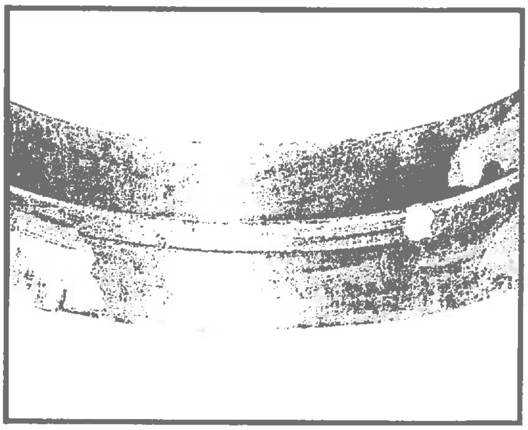
Oil starvation damaged these bearings. Lack of oil can occur immediately after overhaul, when priming of the lubricating system is vital.



After break-in, other things can happen. Both local and general oil starvation can result from external leaks. Blocked oil suction screen, oil pump failure, plugged or leaking passages, failed relief valve springs, or badly worn bearings can stop the circulation of lubricating oil.

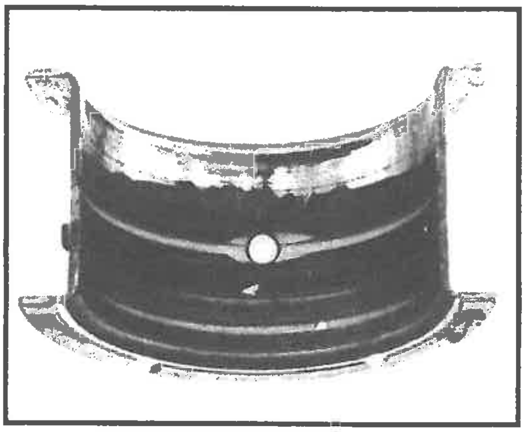
A mislocated oil hole will also cut off the oil supply to a bearing, causing repeat failure. Always check to be sure the oil hole in the bearing is in line with the oil supply hole.

Also, in the case of engines, the oil supply may become diluted by seepage of fuel into the crankcase from a failed fuel pump or stuck carburetor float valve. This will reduce the oil's film strength and the friction will score the bearings.



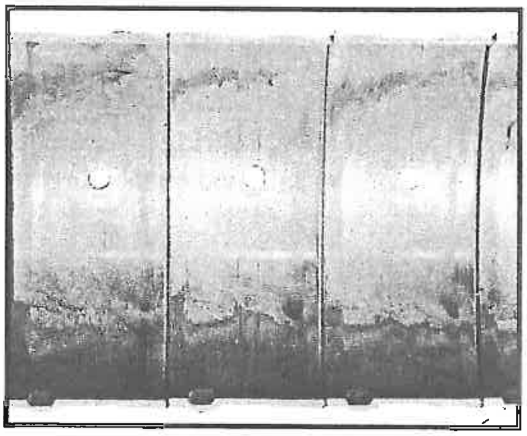
Improper Assembly

Improper assembly and the resultant damage to the bearing can be caused by a tapered journal, out-of-round bearing bore, incorrect crush, or rod misalignment.

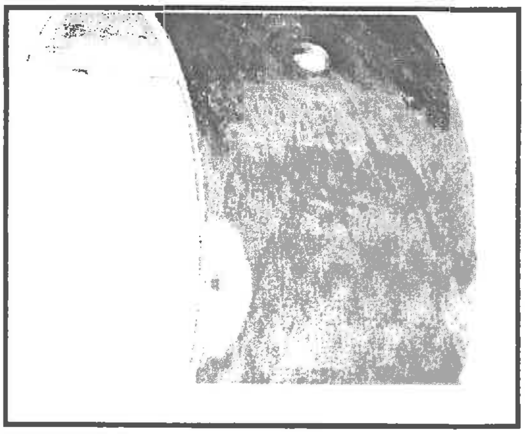


Tapered journals allow areas of excessive clearance between the journal and bearing, distributing more wear onto the edge of the bearing. This wear is increased by the force on the bearing carrying the greater load.

Out-of-round bearing bore usually is visible by lining wear pattern at paring edges, so high wear rate and heat takes place in this area.



A small amount of the bearing insert extends beyond parting edges of rod and rod cap. When the rod bolts are tightened, the bearing inserts are seated. This condition is called "crush". Crush built into the bearing inserts by bearing manufacturers is determined by experience and engineering data, and should under no circumstances be altered. As recommended, torque value is applied to the bearing halves, a squeezing action takes place due to correct crush being present at paring edges. This pressure hold the inserts secure in correct position.



Excessive crush frequently results when someone files parting edges of bearing caps. Excessive crush brings about inward collapse of the bearing insert resulting in premature bearing failure and crankshaft damage.

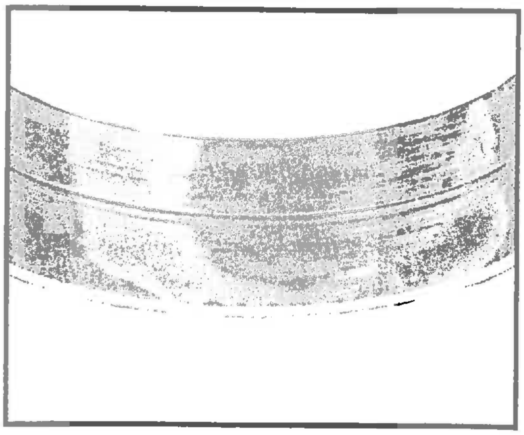
The opposite of excessive crush is insufficient bearing crush which can result in destructive action to both bearing and crankshaft. Any polished area on bearing insert back, or at paring edges, is a true indicator of insufficient crush. Polishing action is caused by bearing movement in bearing bore. Insufficient crush causes loss of heat transfer and bearing lining failure. A few causes of insufficient crush are:

- Insufficient torque because of damaged mating surfaces at parting edges of caps and bores.
- Capscrews bottoming in blind threads, resulting in false torque reading
- Bearing bore wear or cap stretch.

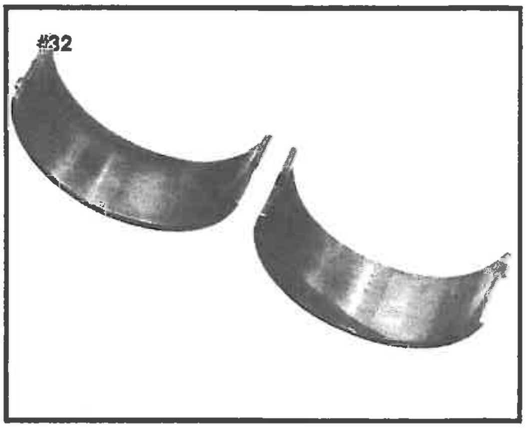
Misalignment

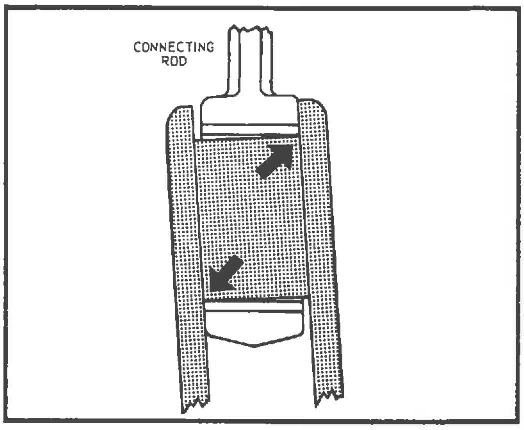
Heavy wear on outer edges of upper and lower bearing inserts could indicate a misaligned connecting rod. Misalignment is caused by:

- Operational abuse such as excessive lugging
- Faulty connecting rod installation
- Abuse of or damage to connecting rod in work area prior to assembly in engine.



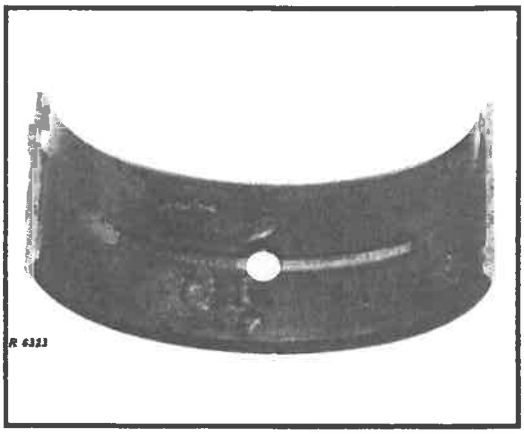
Misalignment can cause concentrated wear on the bearings - one edge of the upper bearing and the opposite edge of the lower bearing. When this wear pattern exists, check the alignment of the shaft and bearings.





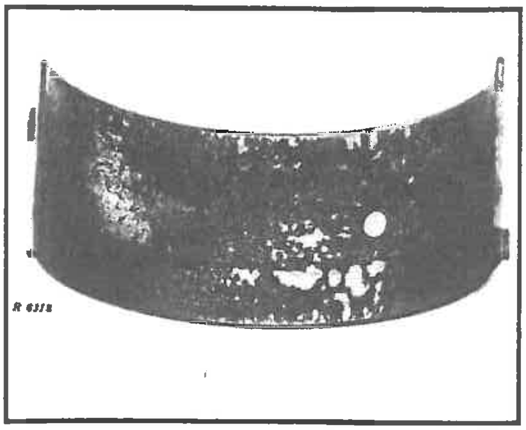
Overloading

Overheating from overloads causes a metal fatigue which breaks away from the surface of the bearing.



Corrosion

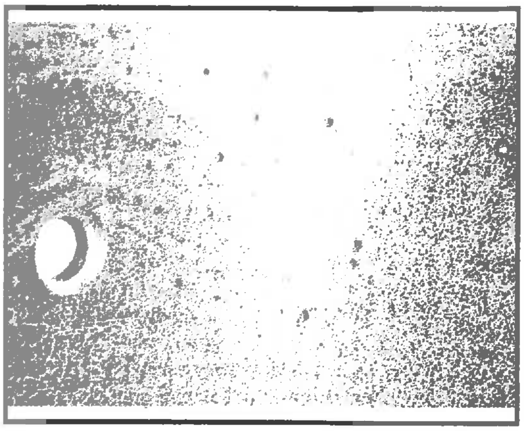
Corrosion from acid formation in the oil causes finely pitted surfaces and large areas of deterioration.



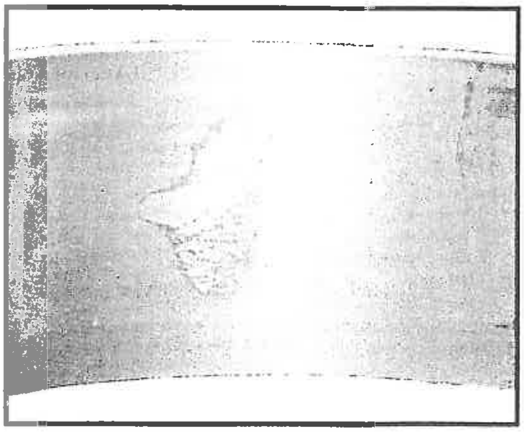
Corrosion occurs when oil temperature goes very high and when excessive blow-by occurs in engines.

Condensation, and in some cases, incorrect lubricant will also cause corrosion.

Prevent corrosion in engines by changing oil at correct intervals and by selecting oil of the proper quality and classification for the machine and type of service. Follow the manufacturer's recommendations.



This shows corrosion of the lead in a copper-lead bearing. **Probably the biggest source of corrosive attack is the oxidation products formed in oil itself.**



Erosion consists primarily of a mechanical washing-away of the bearing surface by the oil stream between the journal and the bearing. The formation and collapse of air bubbles within the oil can lead to extremely high localized pressure which result in localized fatigue and pitting of the bearing surface by "cavitation erosion" as shown.

VALVE GEAR TRAIN

INTRODUCTION

The valve gear train in a typical engine consists of the camshaft(s) tappets, rocker arms, valves, and valves springs. The failure of these parts are described in this section.

IDENTIFYING VALVE FAILURES

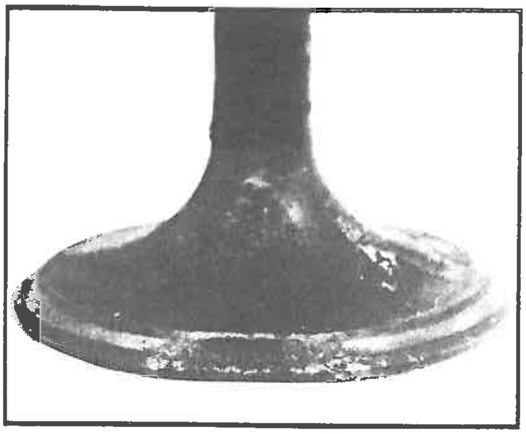
Of all the components of the valve train, valve failures, particularly exhaust valves, represent the more common problems.

The major causes of valve failures are:

- Distortion of the valve seat
- Deposits on the valve
- Too little tappet clearance
- Scuffing of the stem
- Erosion
- Heat fatigue
- Breaks
- Wear

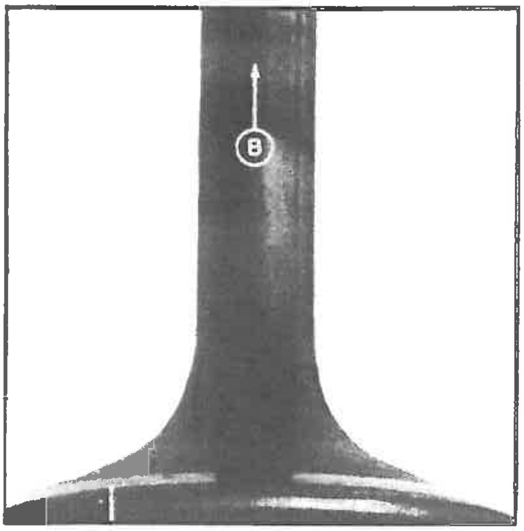
Distortion of Valve Seat

The valve is burned because of distortion of the valve seat. Major causes of seat distortion are:



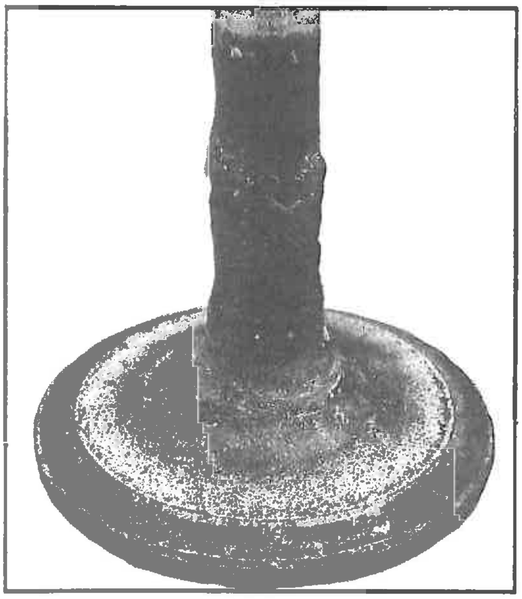
- Failure in the cooling system
- Out-of-round or loose seat. This may stop the transfer of heat between the insert and the head.
- Warped sealing surfaces on heads often distort the seats when the head is tightened. Improper tightening, too much torque and the wrong sequence can also distort valve seats.
- Failure to grind the valve seat concentric with the valve guide hole.

Intake valve stem discoloration (B) indicates too much heat.

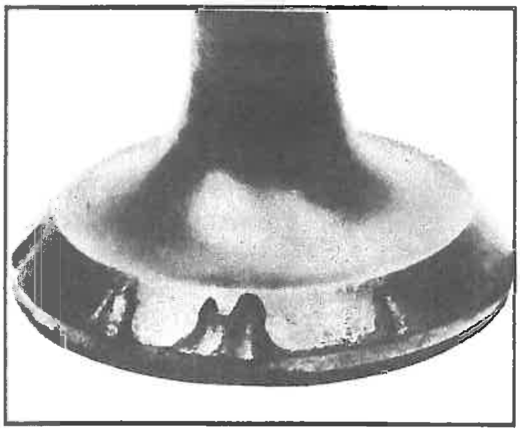


Deposits on Valve

Deposits on the valve stem result from too high a valve stem temperature for the oil being used. There was an apparent lack of heat flow from the valve stem to the guide and from the guide to the cylinder. The heat was trapped in the guide, resulting in excessive carbon formation.



This valve failed because face deposits built up and then broke off. This damaged the seat and the resulting "blow-by" burned the valve.

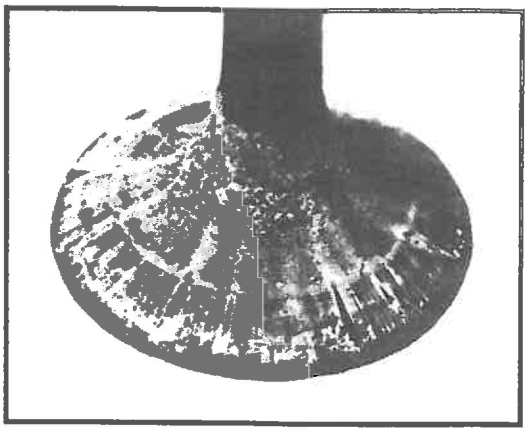


Other factors that may cause this type of failure are:

- Weak valve spring causes a poor seal between the seat and the face, allowing deposits to form.
- Too little tappet clearance also causes a poor valve-to-seat seal.
- Valves sticking in the valve guide allows deposits to build up on the valve face and seat.
- Valve seats that are too wide cut down the seating pressure and reduce the crushing of deposits when the valve closes.
- Lack of valve rotation (which is needed to "scrub" the valve).

Too Little Tappet Clearance

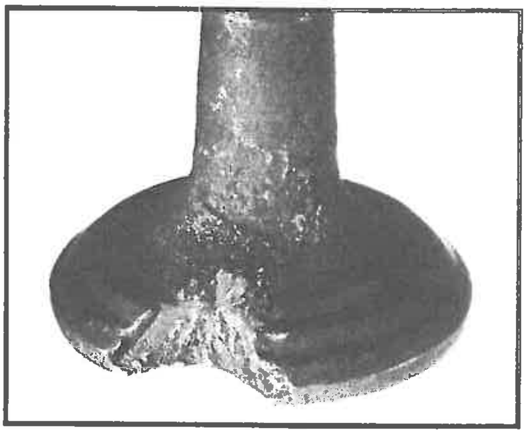
Failure of the valve was caused by too little tappet clearance. The valve was held off its seat and blow-by caused face-burning. Causes of too little tappet clearance are:



- Tappet clearance not set to specifications
- Cooling system not operation properly or wrong thermostat.
- Extremely high temperatures affect tappet clearance
- Valve face material is too soft allowing the valve to recess into the seat.

Burned Valve

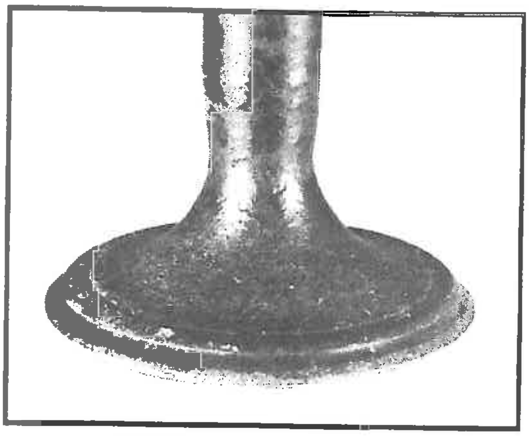
The valve burned and failed as a result of preignition. Valve temperature became so high that part of valve face melted away.



For other causes of burned valves, refer to the previous category.

Erosion of Valves

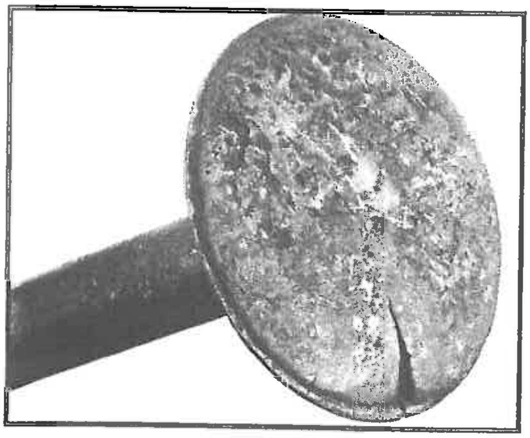
This valve is eroded, but has not failed. However, it would have broken after much more service because of the erosion under the head.



- Causes of erosion are:
- Wrong type of fuel
- Faulty combustion
- Too high valve temperatures
- Lean fuel-air mixtures which overheat valves and erode them.

Heat Fatigue

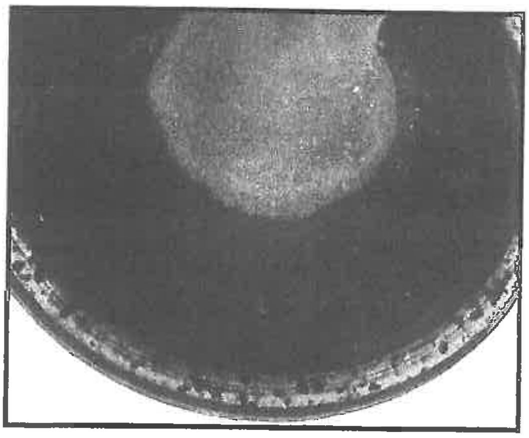
Overheating can crack the valve head. More cracking may cause parts of the valve to break off.



- Causes of cracked valves from heat fatigue are:
- Worn guides
- Distorted seats
- Lean fuel-air mixtures

Pitting

Carbon particles can build up between the valve and the valve seat. This can cause pitting on the valve surface.

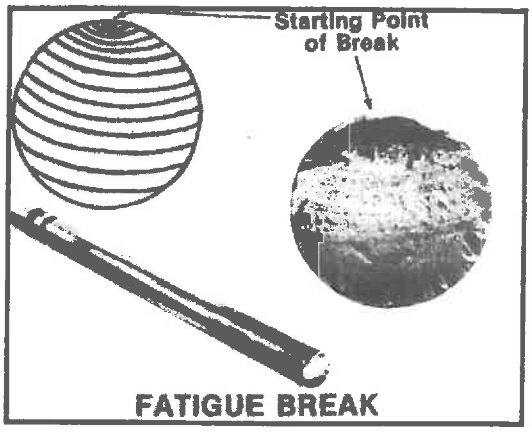


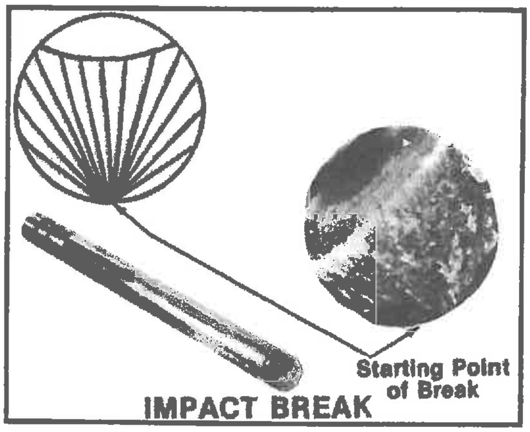
Breaks

Fatigue break is the gradual breakdown of the valve because of high heat and pressure. A fatigue break usually shows lines of progression as at the top.

Impact break is the mechanical breakage of the valve. The cause is seating the valve with too much force, often caused by too much valve clearance. An impact break does not show the lines of progression, but rather the familiar crow's feet. (see bottom illustration).

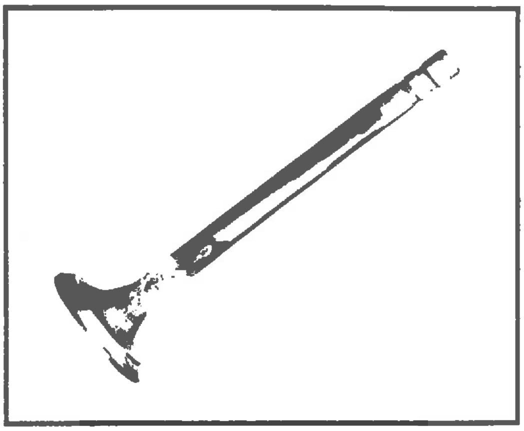
Broken valves are not always clearly one type or the other. Combinations of heat and high seating force can produce failures of varying degrees and appearance.





Wear

This valve failed because of face burning. Wear on the stem and carbon projecting into the guide shows the valve guide was worn and was the likely cause of the failure.



Worn valve guides lead to valve failures:

- Worn guides prevent even grinding of the valve seat leading to out-of-square seating, allowing burning gas to leak out and burn the valves.
- Worn guides cause the valves to strike at an angle and damage the sealing surface leading to blow-by and burning.
- Excessive stem-to-guide clearance or defective valve stem seals allow too much oil to run down the stem, resulting in excessive carbon deposits that cause valve sticking.
- When the inside edges of the valve guides wear, they can no longer act as carbon scrapers.

Other factors can also cause valve guides to fail prematurely:

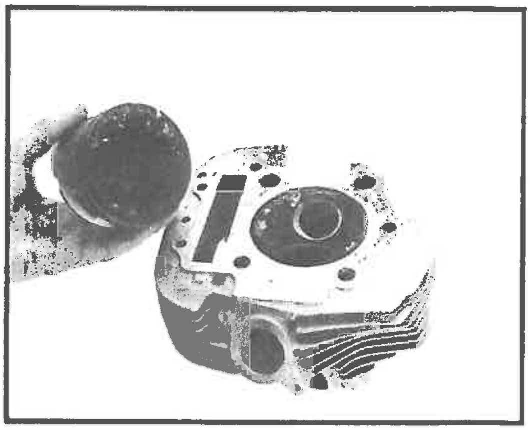
- Worn rocker arms cause excessive side thrust on the valve stem
- Poor lubrication results in scoring
- Carbon deposits on the valve stem wear the valve guide into a bell-mouthed shape
- Cocked valve spring places side thrust on the valve stem, and results in excessive wear

MISCELLANEOUS FAILURES - VALVE GEAR TRAIN

Dislodged Valve Seat

This shows valve seat dislodged from the aluminum portion of the cylinder head.

This type of failure is usually related to a manufacturing defect.

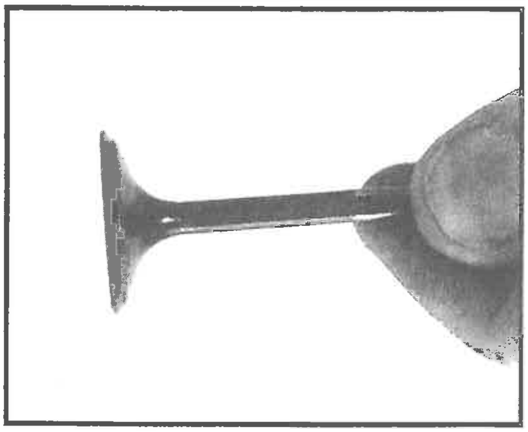


Valve Cupping

This shows valve seat face cupping.

This failure is caused by:

- Sustained high RPM operation
- Poor hardening of the valve
- Poor sealing between the valve face and valve seat



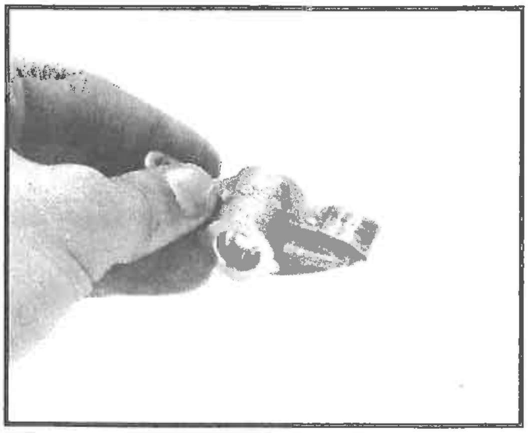
Worn Rocker Arms

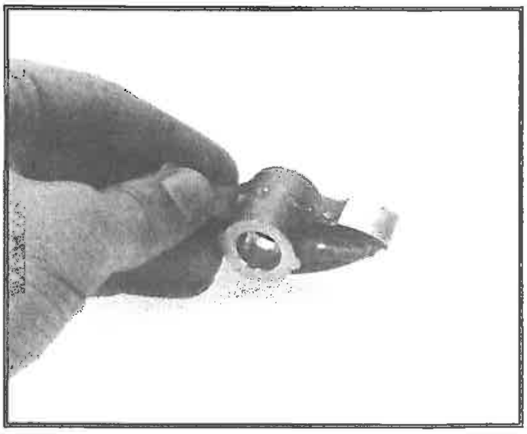
This shows excessive wear on the rocker arm to camshaft contact surface. The second photo shows a normally worn rocker arm.

These failures are usually caused by:

- Lack of lubrication to the engine top end.
- Improperly hardened camshaft or rocker arm

If the rocker arm is badly worn, replace the rocker arms and camshaft as a set.



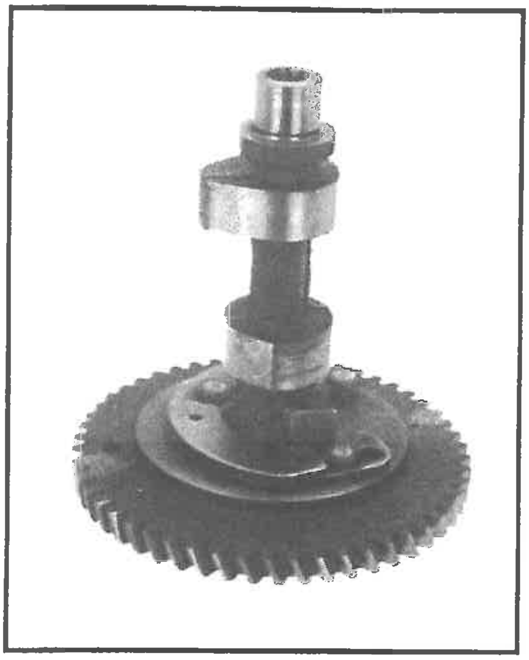


Worn Camshaft

This shows excessive wear on the camshaft lobe.

This type of failure is usually caused by:

- Oil diluted with foreign debris
- Improperly hardened camshaft



INTRODUCTION

The principal causes of gear failure are:

- Wear
- Pitting, spalling, case crushing
- Fatigue
- Impact
- Ripping, ridging, and cold flow
- Combined effects

Many gear failures result from overloading a gear from impact and shock loads brought on by improper shifting or clutching. Under normal recommended loads, most gears perform satisfactorily.

Only an examination by a metallurgical laboratory can definitely determine if certain imperfections exist in a gear.

NOTE: Some imperfections can be obvious.

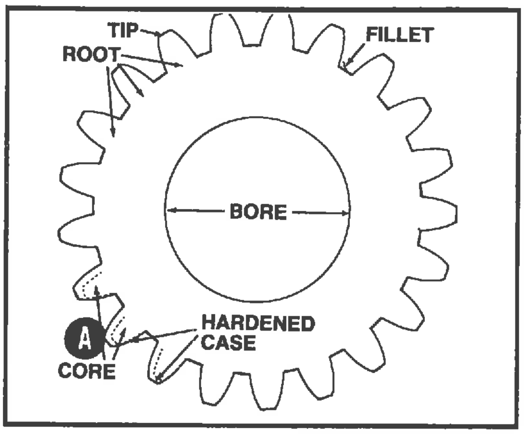
Gear Terminology

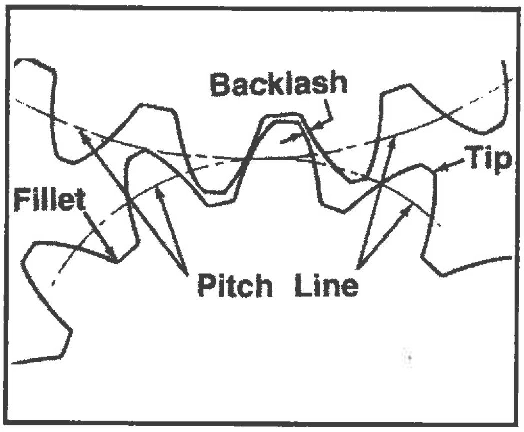
Parts of the gear that are discussed in this chapter are shown in Fig. A. These terms apply to all types of gears.

Some gears are case-hardened by heat treatment after they are machined to the final form. A hardened case is produced by heat treatment providing a hard, wear-resistant surface supported by a lower-hardness, tough core.

Fig. B also shows gears with some backlash or clearance between two gears in mesh. Too much backlash can result in severe impact on the gear teeth from sudden stops or reverses of the gears.

Too little backlash can cause failure due to lack of lubrication between the mating surfaces.





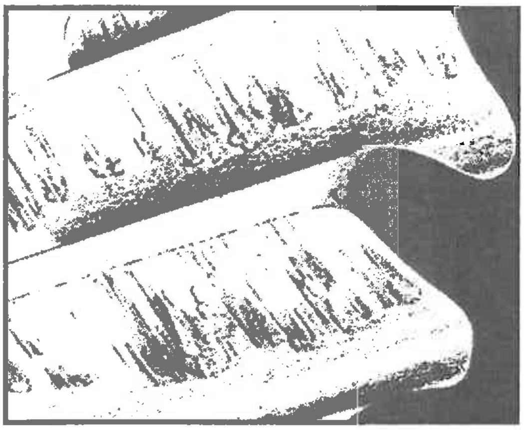
GENERAL CATEGORY OF FAILURES

Wear

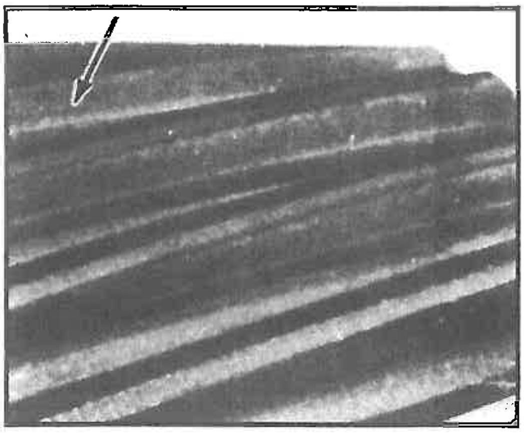
Wear is a removal of surface material from the gear. It can be slow, such as scuffing, or rapid, such as scoring. There are three types of wear:

- Adhesive wear - caused by metal-to-metal contact with surfaces welding together, then tearing apart. Possible causes are inadequate lubrication or the gears not properly in mesh (incorrect backlash).
- Abrasive wear - caused by foreign particles, such as dirt and grit
- Corrosive wear - a chemical attack of the gear surface from contaminated oil or an additive

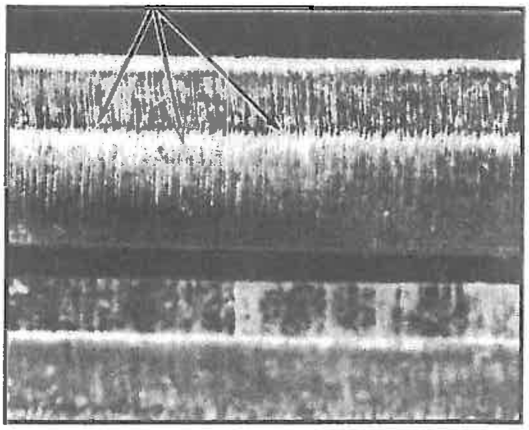
An adhesive type of wear is shown. Possible causes are inadequate lubrication or gears not properly in a mesh



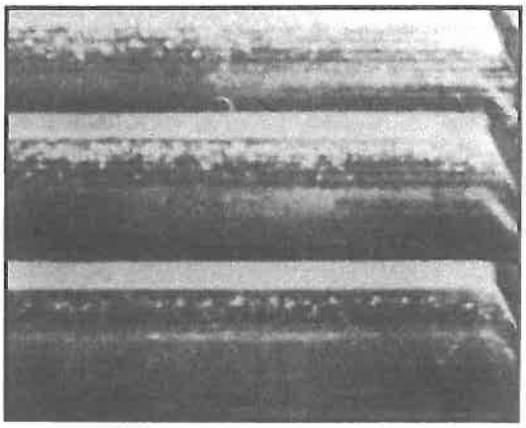
Moderate wear on the face of gear teeth, causes the operating pitch line to become visible (arrow). **A visible pitch line is considered normal wear.** The wear probably was caused by abrasive material in the lube oil.



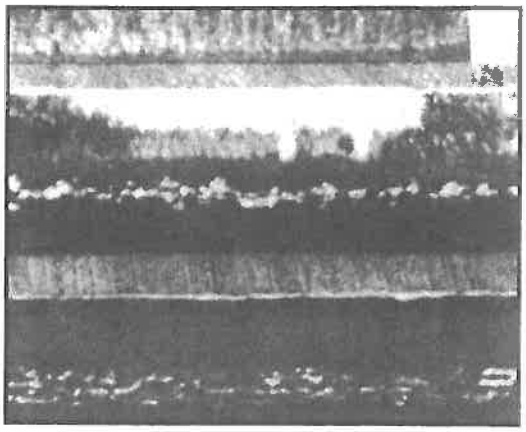
The gear suffered scoring because of metal-to-metal contact under heavy pressure, resulting from inadequate lubrication. The horizontal line on the worn surfaces indicates the pitch line.



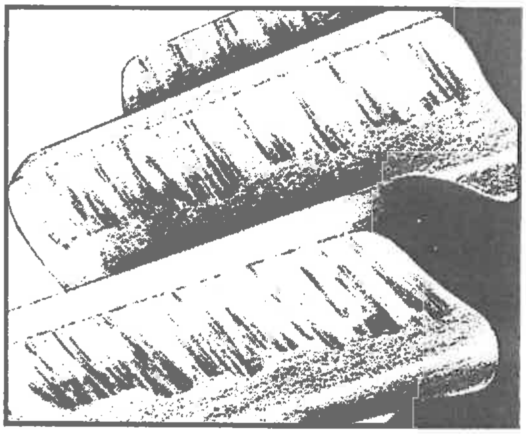
The early stages of scoring shows a spotty frosting pattern on the upper portion of the teeth. Damage is slight at this stage.



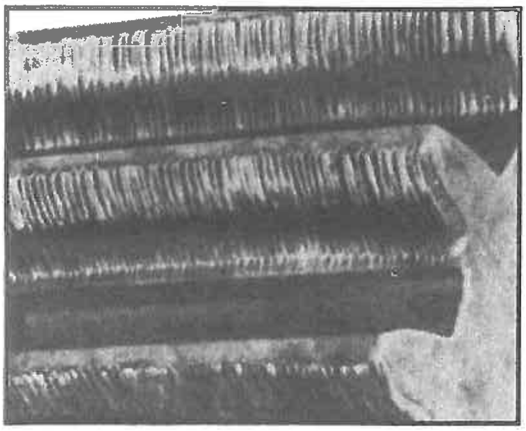
Destructive scoring is shown. Heavy scoring occurred above and below the pitch line. Usually, the damage progresses quickly and the gear fails.



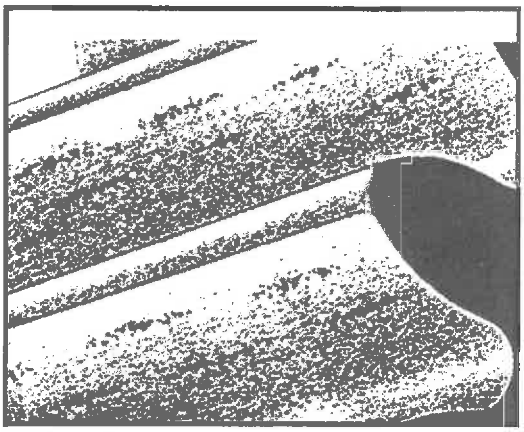
An abrasive type of wear is shown.



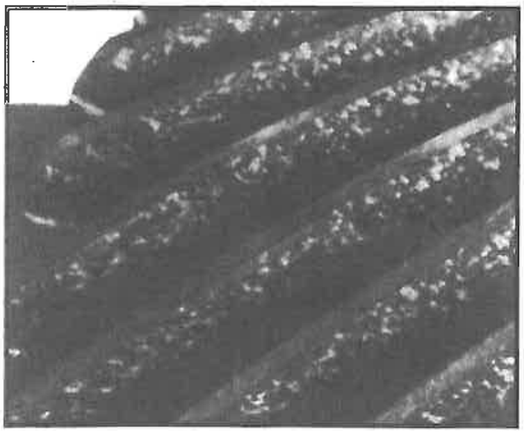
A particularly severe form is shown. A large portion of the tooth of the sintered-metal or bronze pinion has worn away due to an accumulation of abrasive particles in the lubricant.



Corrosive wear is shown. It was caused by contaminants or additives in the oil.

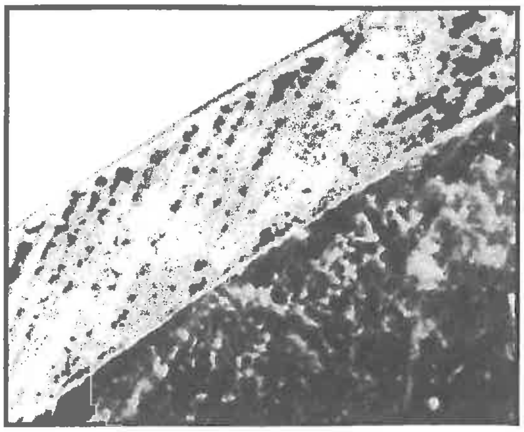


The gear surface was damaged by a chemical reaction. This kind of wear will continue until the gear fails. Chemical wear results from contaminated oil, composition of oil, or an additive.



Pitting, Spalling, and Case Crushing

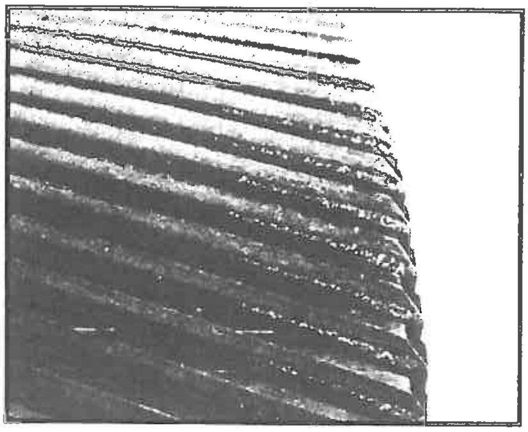
Pits are a type of fatigue failure and appear when small particles of the gear separates from the tooth surface. As the surfaces of mating gears come in contact, the repeated stress on these surfaces can cause pitting.



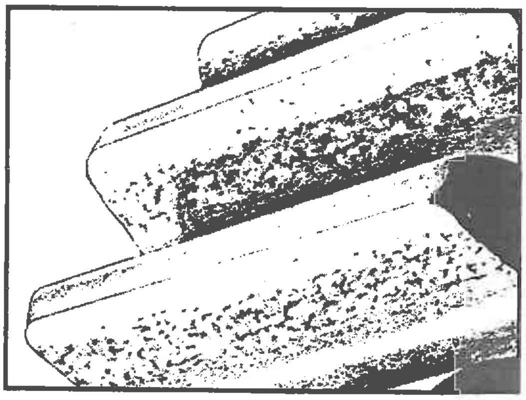
They start along the line of contact where the pressure in heaviest against the teeth of the mating parts and are generally caused by excessive loads. Frequently a fatigue crack will start at a pitted area. Spalls are an advanced state or severe form of pitting and part of the gear may crack off.

Case crushing (crushing the outer, hardened surface of the gear teeth) is generally indicated by cracks running along the face of the tooth. It is usually caused by excessive operating loads.

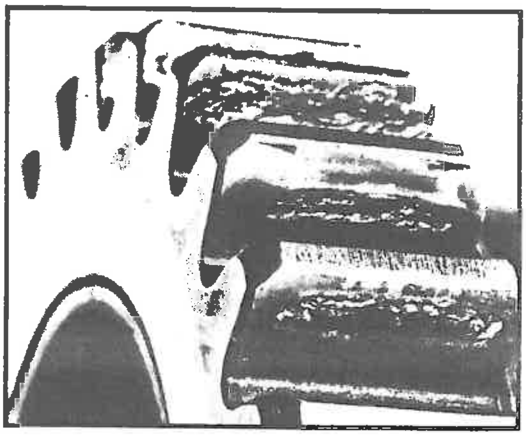
The pitting began on the outside end of the helix (the right edge of the gear in this picture), because of a small amount of misalignment, and worked its way to the middle of the tooth. Eventually pitting stopped and the surface began to polish, indicating that the load across the teeth became more evenly distributed. This type of pitting is not harmful.



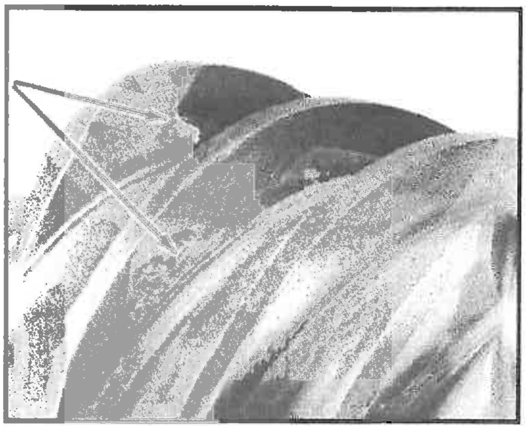
In contrast, this destructive pitting, probably resulted from excessive loads.



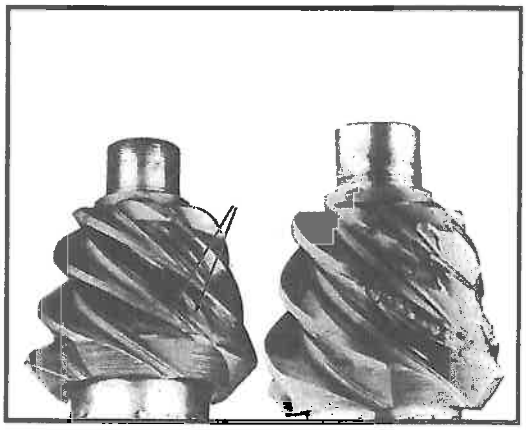
Pitting destroyed the surfaces of the teeth in this spur gear.



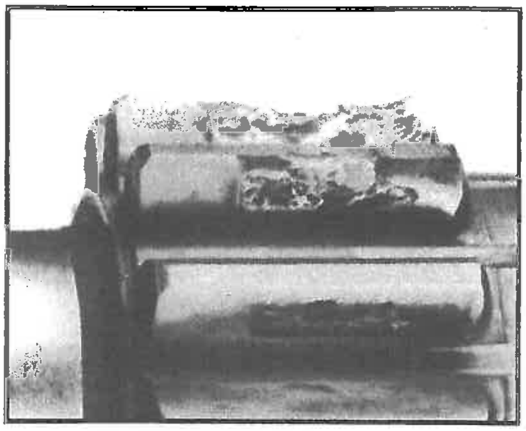
Pitting occurred at the heel contact. Heavy contact occurred at the location of the pits because the tooth surfaces did not mate properly, possibly because of an overload.



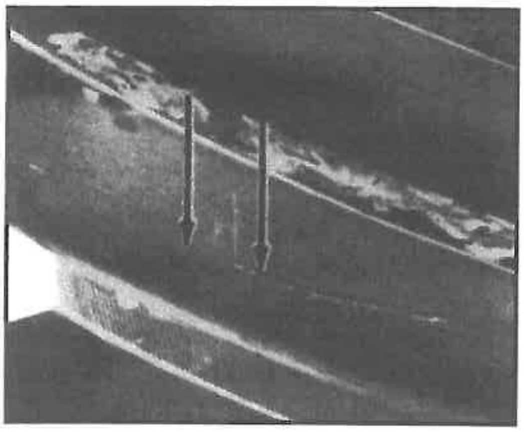
In the first stage of spalling, cracks running lengthwise developed on the contact area of the teeth. Spalling completely destroyed the gear when the large fragments come out, as shown.



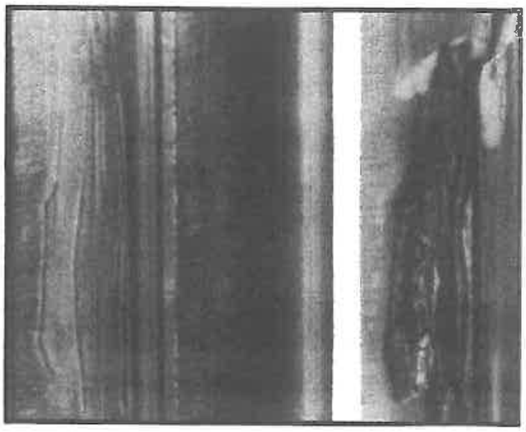
The drive pinion shows severe heavy pitting, spalling, and complete tooth destruction on successive teeth.



Case (hardened surface) crushing, is shown by lengthwise cracks in the contact surface of this bevel gear. The major cracks began deep in the case-core structure and worked their way to the surface. Long chunks of material appear about to break loose from the surface.



The initial appearance of case crushing of a carburized gear (a gear hardened by heating the surface, converting it to high-carbon steel, then quenching) is shown at the left and the final stages at the right.



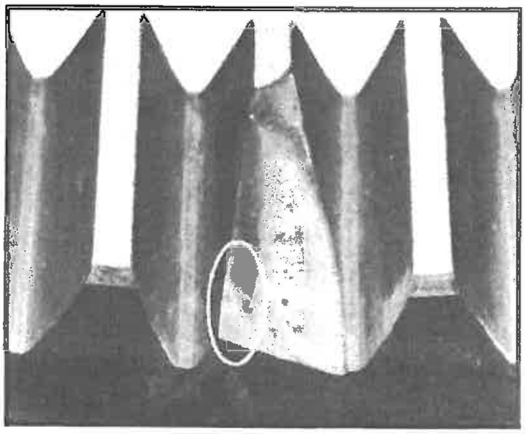
Fatigue

Fatigue is generally due to repeated, excessive loads that fracture gear teeth, usually at or near the tooth root.

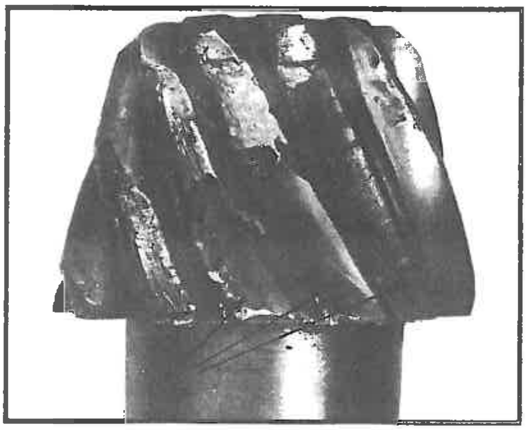
Fatigue failure may start as a small crack, caused by an extremely high load, and continue under normal operation until the gear fails. The fractured face usually consists of two zones:

- The smooth fatigue zone, with progressive stages of crack growth
- The final-fracture zone which is rough

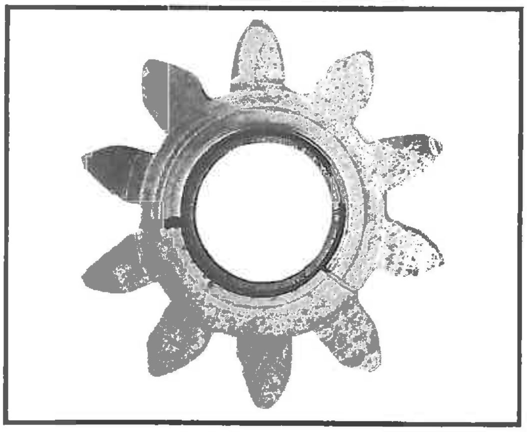
A typical fatigue failure of a ring gear, with its characteristic smooth zone, is shown. The failure probably resulted from a heavy load or shock load (improper shifting or clutching).



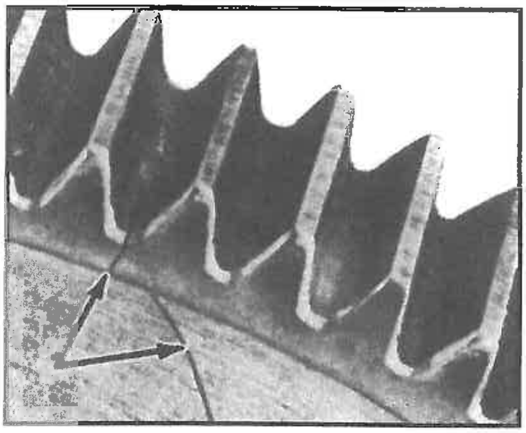
This shows fatigue at the root of three pinion teeth.



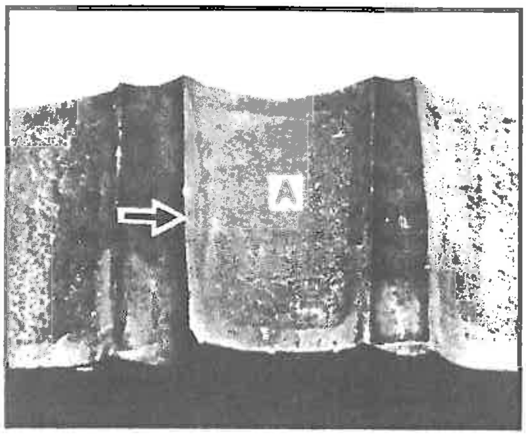
This gear failed from fatigue with severe tooth wear. The fracture extends from root fillets (the area connecting the bases of the teeth) to the bore in the gear.



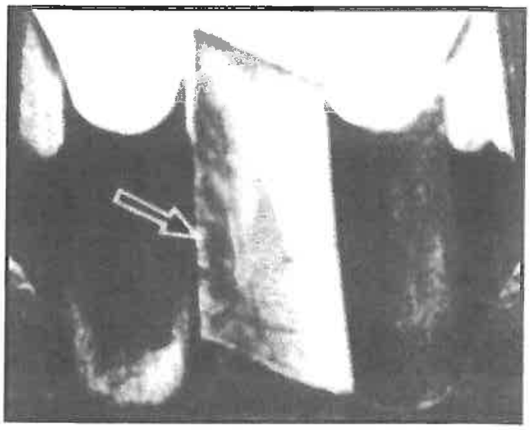
A fatigue crack extending from the root fillet to the bore.



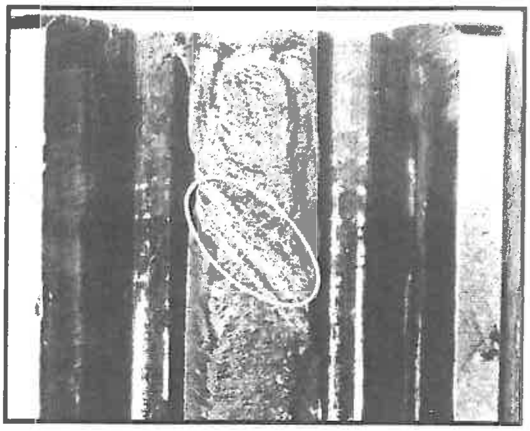
Fractures caused by repeated, heavy loads on several teeth of a spur gear are shown. The tooth marked "A" apparently broke first (note smooth velvety zone) as a result of a fatigue crack.



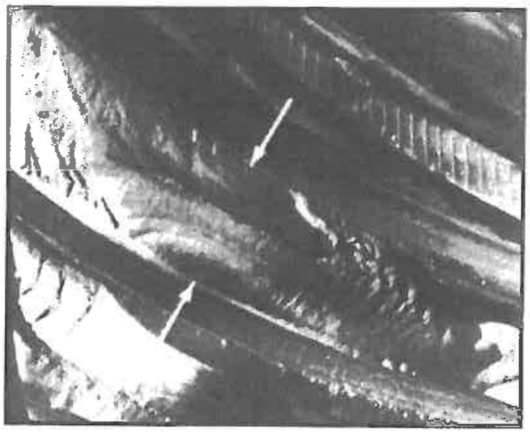
Another fatigue fracture is shown. The arrow indicates the crack origin at the left edge of the fracture, where a small pit existed near the base of the contact area on the pressure side of the tooth. The area just beside the crack origin (at arrow) is well rubbed, which indicates that the crack progressed slowly at first.



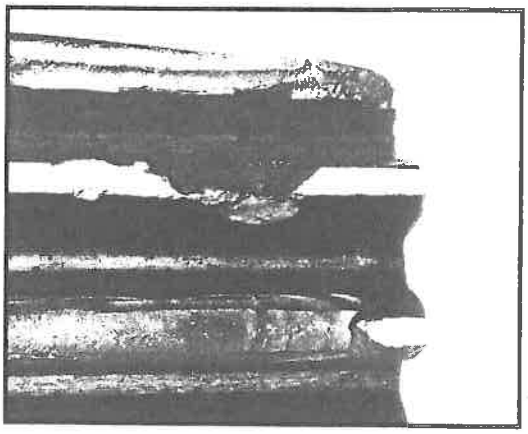
This gear failure consists of one broken tooth and cracks in the adjacent teeth. Since the fracture face was not smooth it indicates an instantaneous fatigue fracture. A pronounced band of inclusions (impurities in the gear), which act as notches promoting failure, were also observed.



Fatigue cracks in a case hardened gear (hardening the outside surface of the gear) began in tooth roots, forming on either side of a tooth (arrow), and meeting in the middle of the tooth.



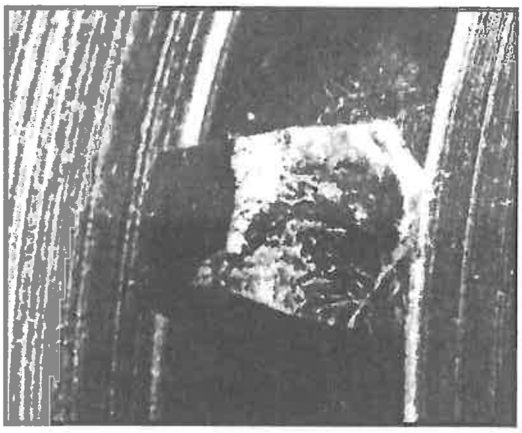
This gear had most of the tips of the teeth broken off. Stresses from service loading initiated cracks at this point. Ultimately, these cracks continued, probably by fatigue, to the surfaces of the teeth. If this happens after brief service, there may have been excessive depth of the hardened surface.



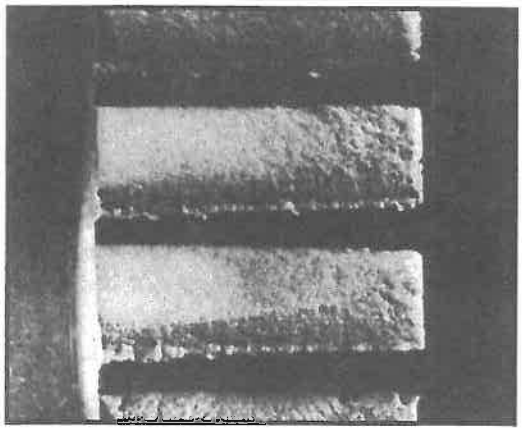
Impact

Impact failures are generally caused by severe loads resulting from abusive service. The failure usually takes place at or near the tooth root and the fractures face is gray and grainy, without evidence of progressive failure.

Battered and chipped tooth corners in carburized gears received repeated blows before fracturing and hid many of the fracture-surface characteristics. Improper shifting probably caused this failure.



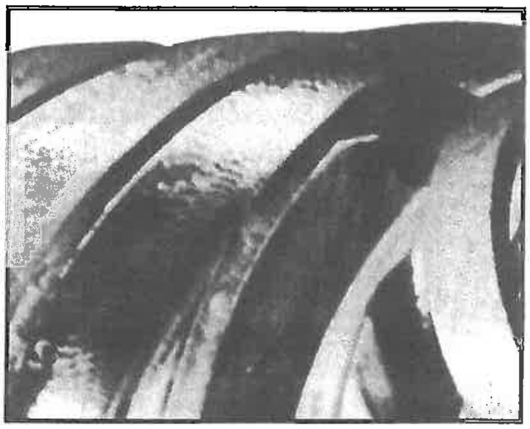
The break in the hardened spur gear has a gray, grainy appearance typical of the shock failure. It does not have the smooth appearance characteristic of fatigue. The failure probably resulted from improper clutching or improper shifting.



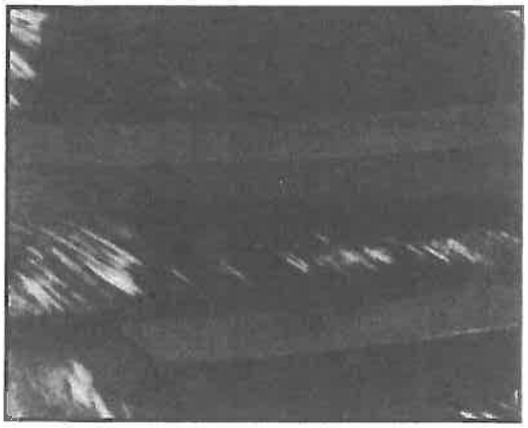
Rippling, Ridging, and Cold Flow

Rippling, ridging, and cold flow (metal movement under high pressure at room temperature) occur less frequently than those previously described and tend to be less damaging.

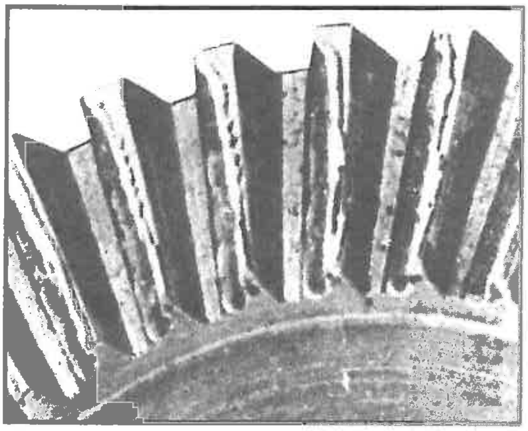
The surface of this gear shows waviness; a typical case of rippling on a hardened hypoid pinion. Rippling generally occurs on highly loaded gears.



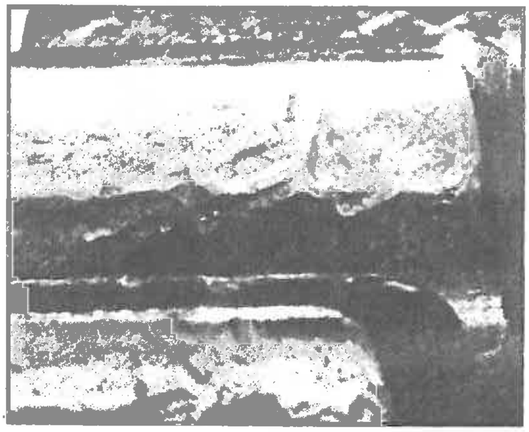
The hardened gear is ridging possibly because of an overload.



This shows an advanced stage of cold flow in a medium hard gear. Such gears have a greater tendency for cold flow than case hardened gears. Material has been rolled over the top edges of the gear teeth resulting in a destruction of the gear tooth profile. Heavy loads probably caused this type of metal movement.

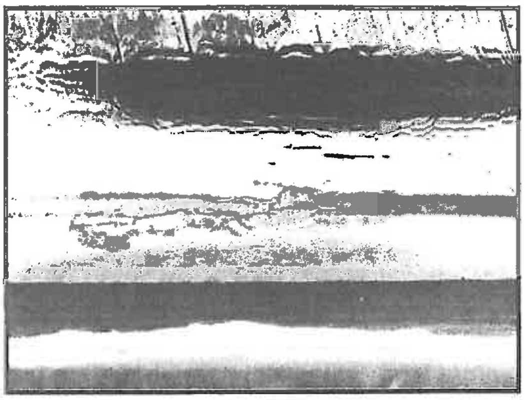


The medium hard gear shows surface deformation due to rolling and hammering action. This gear probably was overloaded and operated long after the initial damage occurred, resulting in a battered surface.

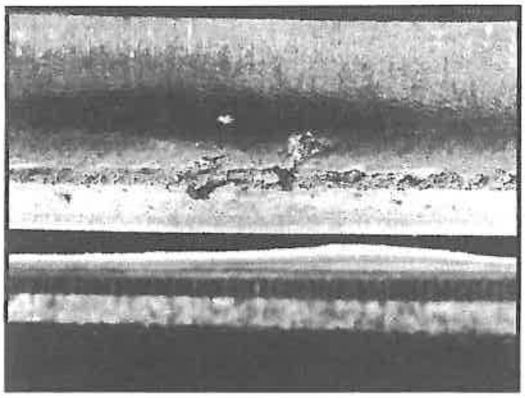


Combined Effects

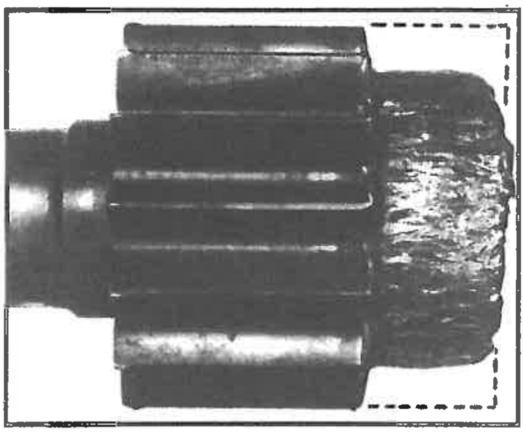
Severe contact stresses caused plastic flow at the surface of the gear producing ripples. Spalling (chipping of surface material) also occurred near the tooth center. Excessive loading may be the cause of this type of failure.



A carburized drive pinion pitted near the pitch line. Also apparent are rippling along the pitch line and slight adhesive wear near the top, probably caused by overloading the gear.

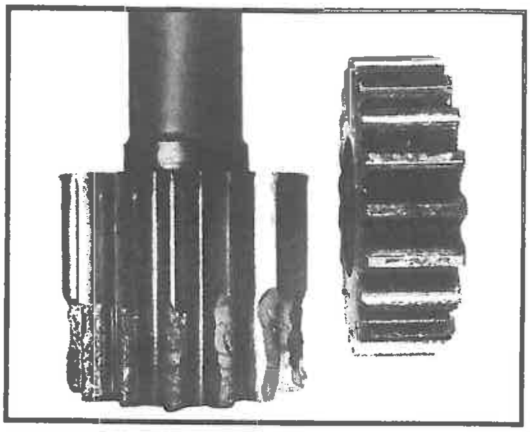


The final drive pinion failed and there was a complete destruction of the contact portion of the pinion teeth. This was probably caused by heavy loading or inadequate lubrication. The gear teeth extended to the end of the shaft before the failure occurred.



The pinions failed by advanced pitting and adhesive wear. Extreme overloading and inadequate or improper lubrication were probably the causes of these failures.

The gears show severe battering and fatigue, probably caused by severe overloading or inadequate lubrication.

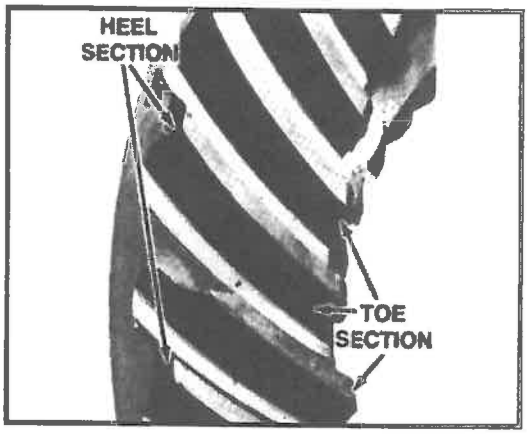


SPECIFIC CATEGORY OF FAILURES

Ring Gear Teeth

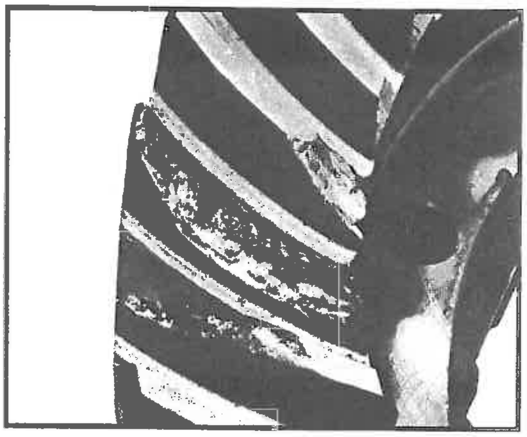
A typical example of a fractured bevel gear tooth due to improper adjustment is shown. The failure resulted from excessive loading at the heel section of the bevel gear.

Excessive backlash probably caused the failure.



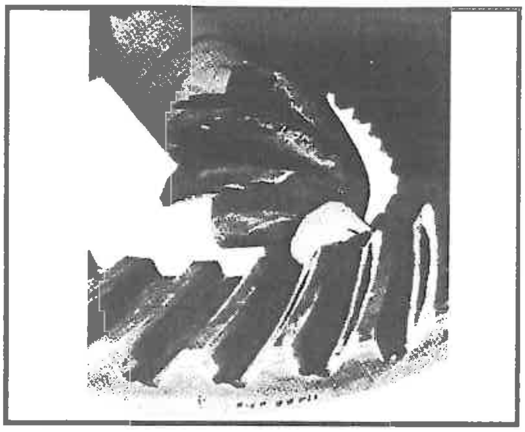
The fracture resulted from excessive loading on the toe section of the gear, while the cause of failure was insufficient backlash.

Shock loading may also cause these conditions; even to the extent of breaking entire ring gear teeth.



Ring Gear and Drive Pinion

The scuffing is spread over the tooth area. The metal had softened and was drawn across the tooth face.



Abnormal friction between gears creates heat which softens the metal and damages the teeth, if not adequately lubricated.

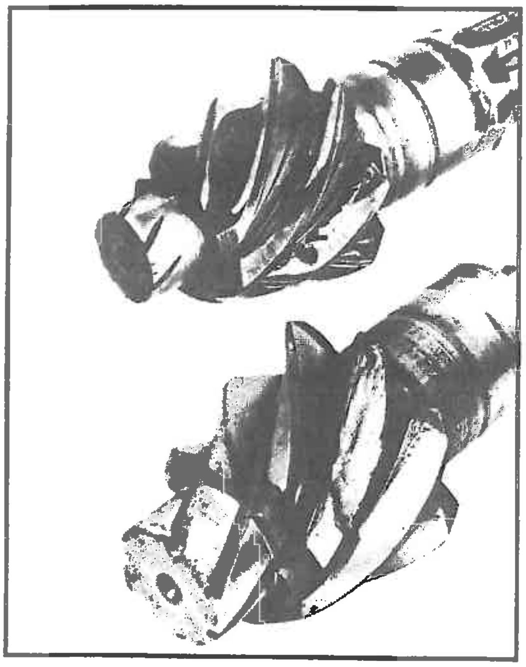
Worn pinion bearings permit end play by the pinion resulting in incorrect tooth contact between pinion and ring gear.

Excessive torque could also be a cause of failure.

The ring gear teeth show discoloration and distortion. This type of failure is caused by heat generated from improper lubricant, low lubricant level, or infrequent lubricant change. In the presence of any of these conditions the surface overheats because of excessive friction.

Drive Pinions

Excessive loading during severe service resulted in concentration of pitted areas at tooth heel. Under excessive loading, deflection throws the pinion out of correct position in relation to ring gear and concentrates the load on the tooth heels.

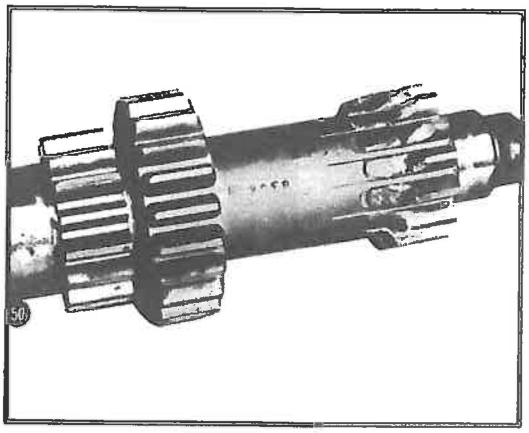


The smooth zone on the face of the broken teeth is where the crack started. The rough zone indicates an area insufficient to resist a single load application.

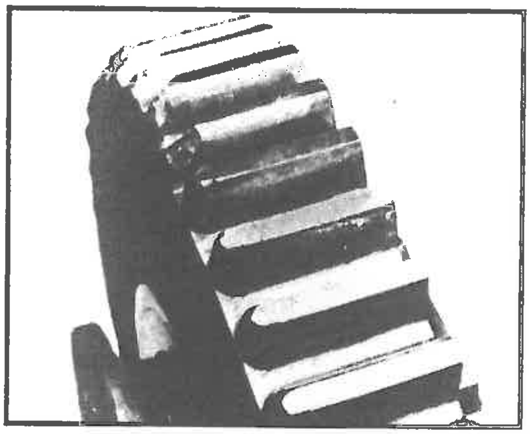
Severe operation, defective material, and inadequate radius at the root of the tooth or poor bonding of the radius and the tooth face can cause this type of failure.

Transmission Countershafts

Snubbed, chipped, and cracked engaging teeth indicate careless shifting. Assure proper engagement and sychronization of gear.



Gear teeth chipped and broken away from the engaging ends of the teeth indicate partial engagement and dragging clutch, which keeps the countershaft turning so that there is interference with gear engagement.



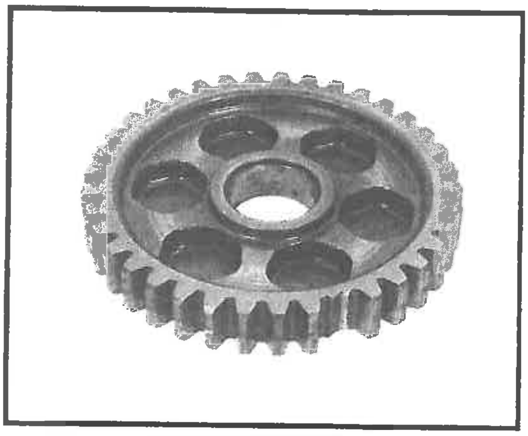
MISCELLANEOUS FAILURES — GEARS & RELATED PARTS

Broken Gear Tooth

This shows gear tooth breakage caused by excessive impact.

Excessive impact may be caused by:

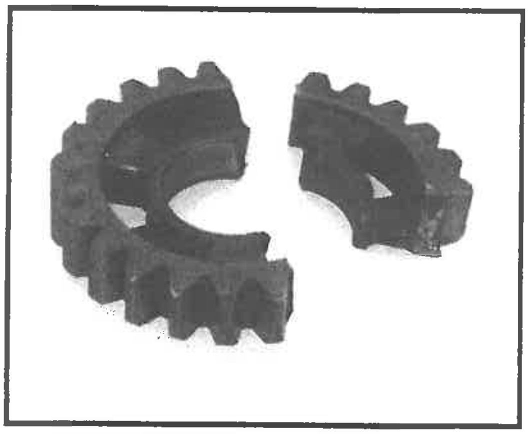
- Clutch not completely disengaged during transmission shifting.
- Abrupt binding of the drive line
- Use of air impact tool on the transmission shaft during assembly



Broken Gear

This shows gear breakage due to excessive impact caused by:

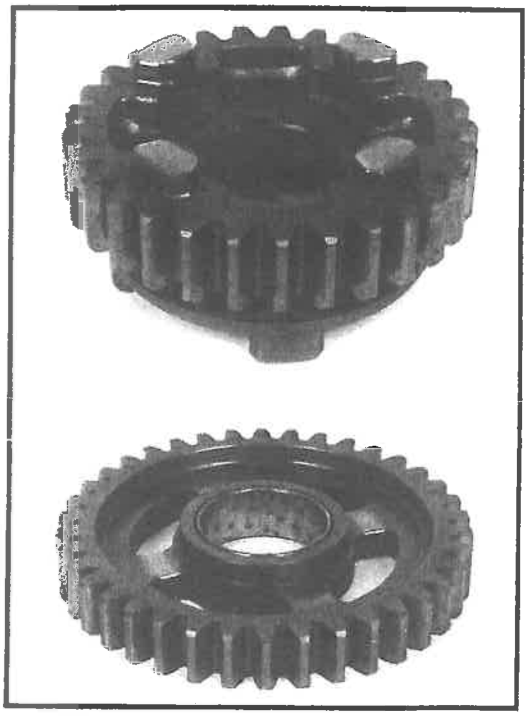
- Clutch not completely disengaged during transmission shifting.
- Abrupt binding of the drive line - such as a broken drive chain binding the counter sprocket or landing a dirt bike off a jump in the wrong gear.



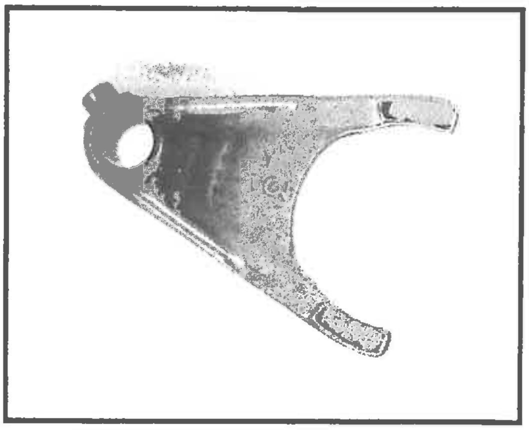
Rounded Gear Engagement Dogs

This shows rounded gear engagement dogs. This type of failure is usually caused by:

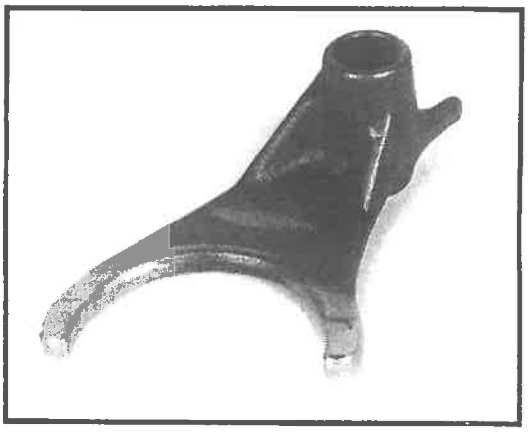
- Bent shift forks - rounded engagement dogs usually cause bent shift forks
- Incomplete or abusive shifting by the operator
- Improperly shimmed transmission



Shift Forks



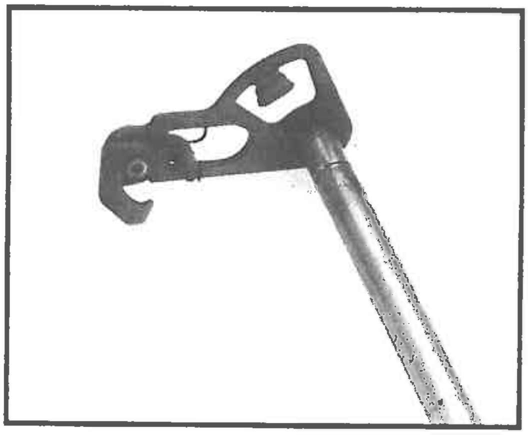
This picture shows a shift fork with normal wear. No signs of burn marks and the fork is not bent. This shift fork should be reused.



This shows an excessively worn shift fork. Wear possible caused by breakdown of lubrication or lack of lubrication.

This fork should be replaced.

Shift Shaft



Breakage of shift catch from shaft

This failure is usually caused by excessive force on the shift lever by the operator or during a fall to the left side.

Broken Spring

This type of failure is usually caused by an improperly hardened spring.

INTRODUCTION

This section is divided into two broad categories:

- General Failures
- Specific Failures

General Failures

The general category applies to failures common to all shafts, axles, and spindles regardless of the application and assembly conditions. The following failures are described first:

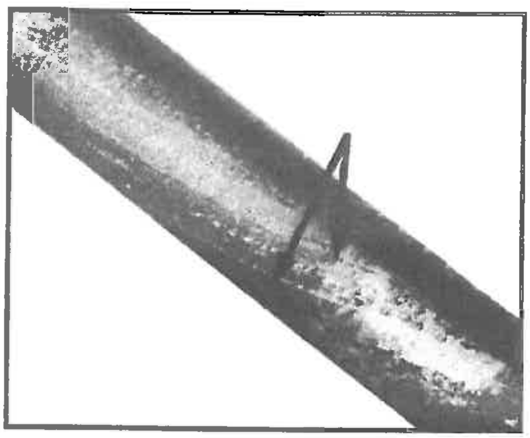
- Overload failures
- Bending fatigue failures
- Torsional fatigue failures
- Combined fatigue failures
- Impact failures

The following specific causes of failure follow:

- Severe service
- Stress concentration
- Fretting and scoring
- Improper usage
- Failure of other related components

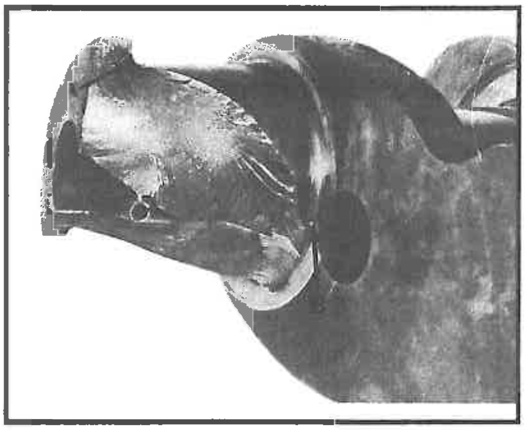
Overload Failure

High static loads tend to produce the type of failure illustrated. Although the shaft has not fractured, it has twisted and is out of alignment. Static load is the weight the shaft must support while sitting still. In this case, an overload probably caused the failure.

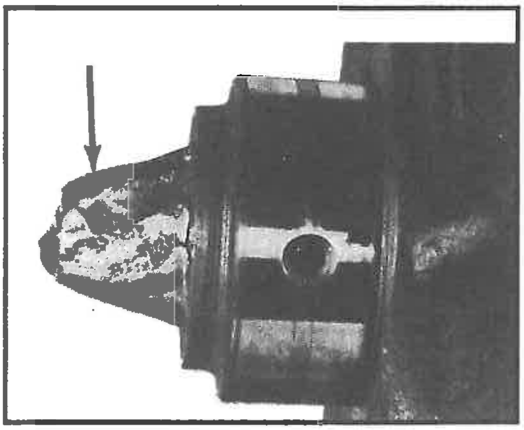


Torsional Fatigue

Failures were caused by twisting loads. Torsional (twisting) loads produce spiral shaped failures.

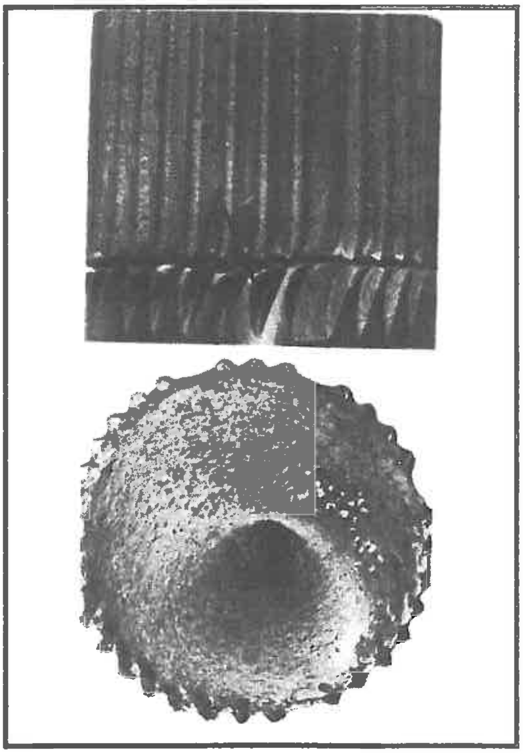


Sometimes the evidence of fatigue is obscured by severe battering at the time of final fracture. The crankshaft failed initially by fatigue.



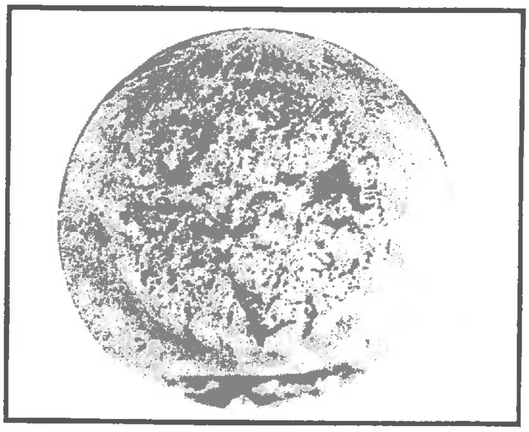
Severe Service

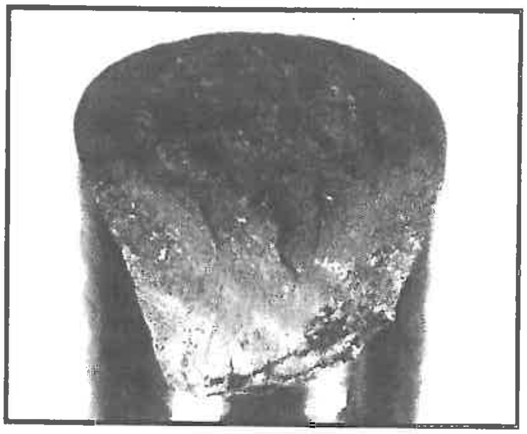
The deformation of the splines in the region of the fracture (arrows) would not occur if the fracture were caused by fatigue. The torsional twisting during an overloaded operation caused the failure.



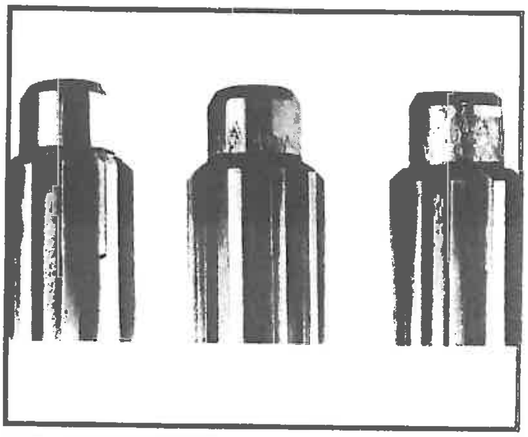
Impact Failures

The face of a fracture caused by impact loading is usually gray, fibrous, and grainy; without evidence of progressive failure as in fatigue. The axle probably was struck by a single blow or overload causing immediate fracture.



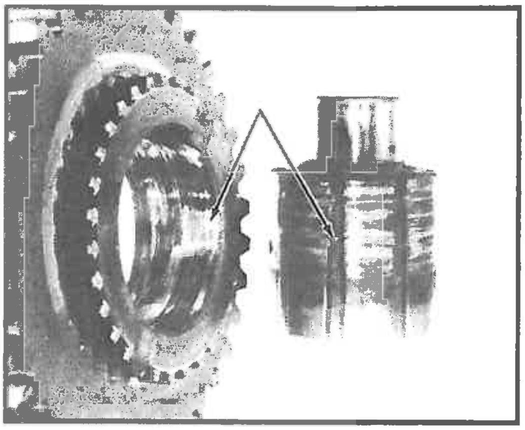


These transmission shafts show the progressive stages of scoring. Scoring is caused by heat buildup between metal parts that rub together.



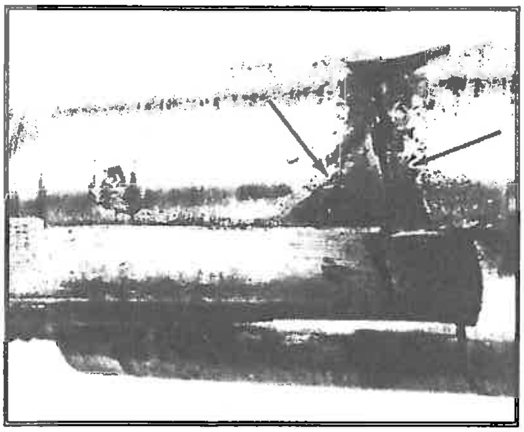
Transmission Shafts

The gear and shaft show galling and overheating (discoloration on shaft beside galled area). Inadequate lubrication caused the failure.



Spindles

A large amount of wear is visible on both sides of the broken spindle.



UNIVERSAL JOINTS (U-JOINTS)

A universal joint is essentially a double-hinged joint transmitting torque at constantly changing relative angles. High loads, lack of lubrication, and abrasive material are usually responsible for most damage found in u-joints. Some recognizable signs of universal joint failure or deterioration are:

- Vibrations
- Universal joint looseness
- Universal joint discoloration because of excessive heat

Many universal joint failures are caused by lubrication breakdown.

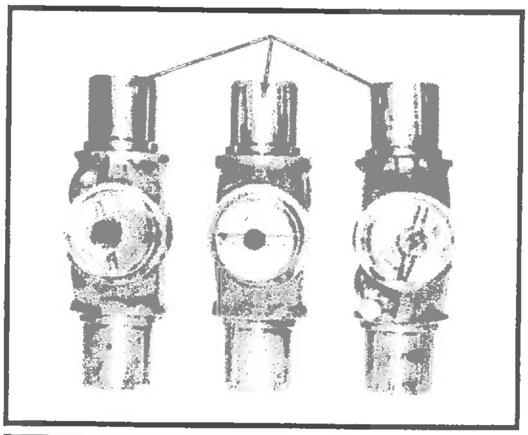
Some common universal joint failures are:

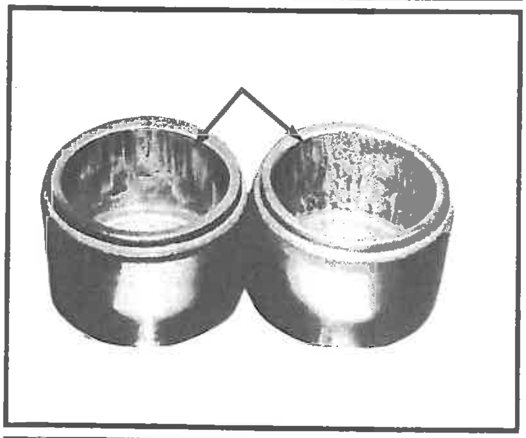
Fatigue

Three stages of journal fatigue failure are shown - early stages at top to severe spalling in the center picture.

Fatigue failures result from applying too high a load for a given joint size and operating at too great an angle. Inadequate lubrication also contributes to early fatigue failure.

Fatigue failures also show up on the inside diameter of a U-joint cup.

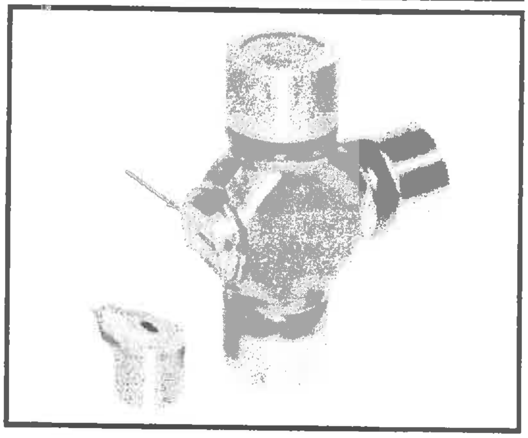




Broken Journal

Journal fracture normally occurs at the base of the trunnion - the point of highest bending stress.

Excessive torques for given U-joint sizes and excessive shock loads cause this type of failure. Sudden drive shaft lockups causing excessive U-joint loads, and high torque fluctuations also lead to broken journals. See bottom illustration

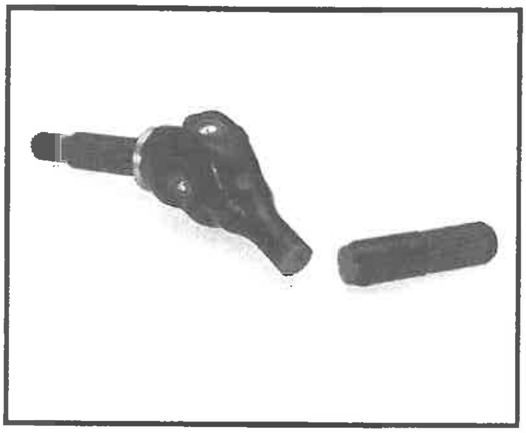


MISCELLANEOUS FAILURES — SHAFTS, AXLES, CONNECTING RODS

Universal Drive Axle

This shows a clean breakage of a universal drive axle. This type of failure is from:

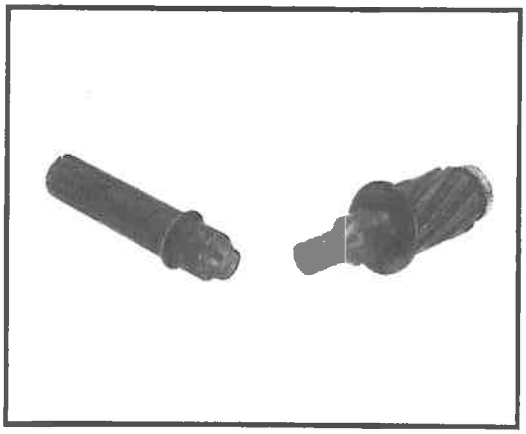
- Excessive load on the axle
- Improperly manufactured drive axle



Drive Shaft

This picture is of a clean breakage of a drive shaft caused by one of the following:

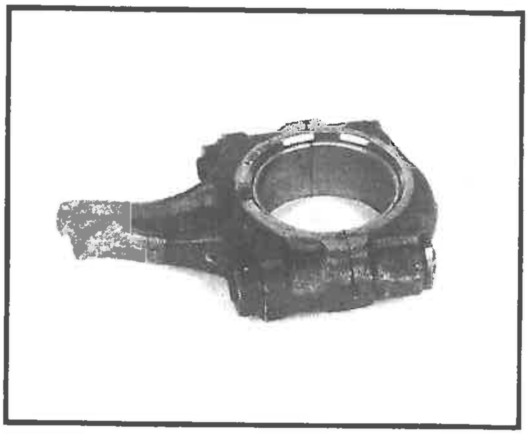
- Excessive force applied to the drive shaft
- Improperly manufactured drive shaft



Broken Connecting Rod

This is a broken connecting rod with rub marks at the broken area.

This type of failure is usually caused by engine hydro-locking and bending of the rod. Hydro-locking is caused by fluid filling the cylinder.

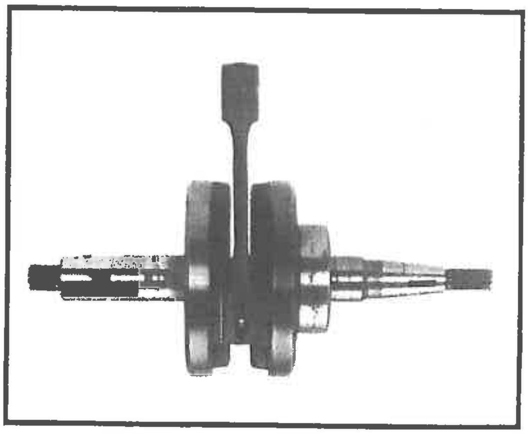


Big End Connecting Rod Bearing Failure

This shows lower connecting rod (big end) bearing failure. The bearing is dry, flattened, and discolored.

This type of failure is usually caused by:

- Lack of lubricant
- Improper assembly (too tight)
- Poor air filtration (2-strokes)

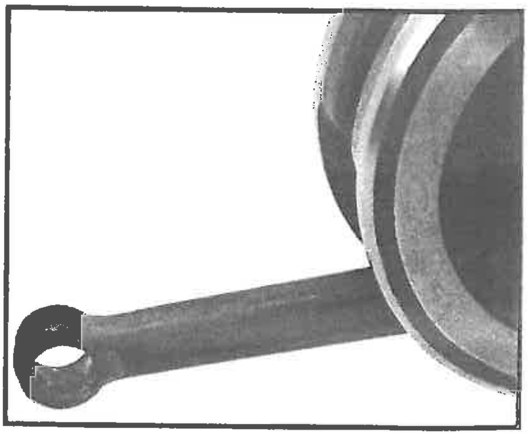


Small End Connecting Rod Bearing Surface Failure

This shows galling and/or scratch marks on the upper connecting rod bearing surface.

This type of failure is caused by:

- Lack of lubricant
- Oil diluted with foreign material

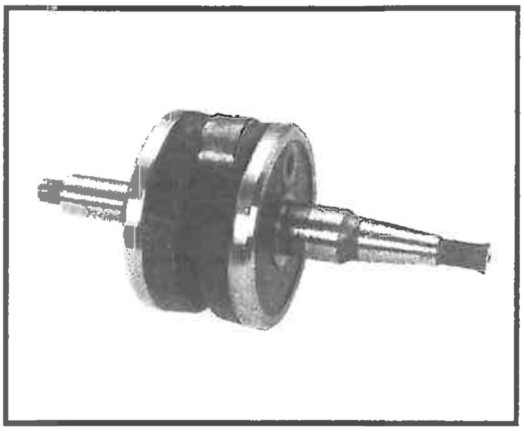


Crankshaft Thread Damage

This illustrates damage to the threads which secure the flywheel. This failure was probably caused by:

- Use of improper tools
- Use of excessive force to remove the flywheel

If the flywheel is difficult to remove, heat the tapered area and try again.



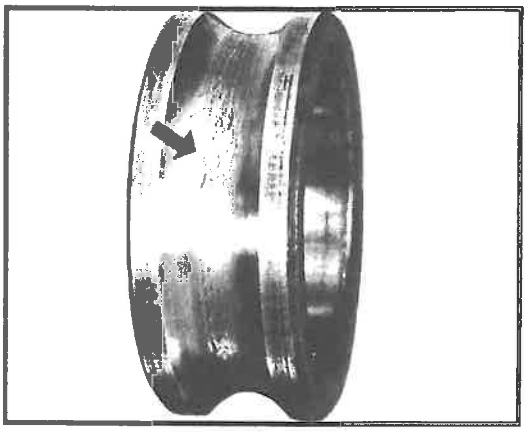
INTRODUCTION

Failures of antifriction bearings are due to a variety of causes, most linked to the following:

- Contamination
- Improper lubrication
- Improper installation
- Careless handling
- Distortion and misalignment
- Severe service
- Defects in bearing material

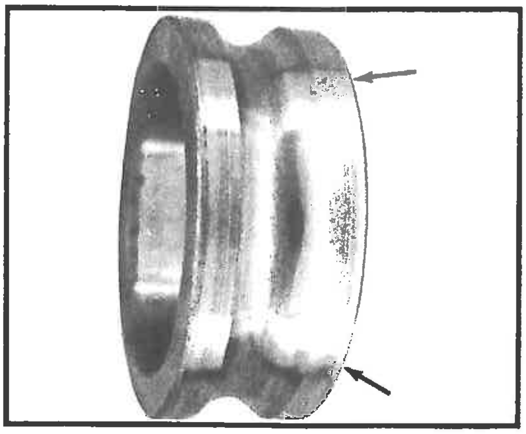
Contamination

Contamination is any foreign matter that will damage the bearing. Moisture and any type of abrasive, such as dirt or sand, will cause premature failure.

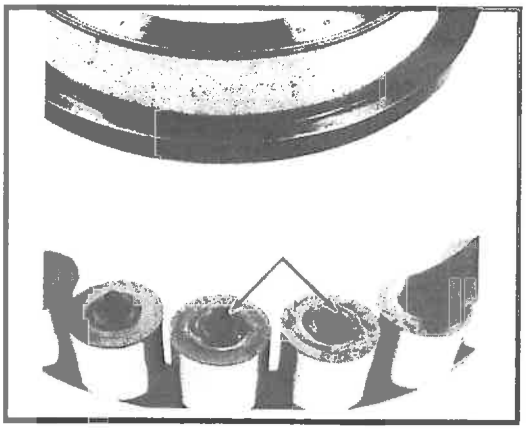


Abrasive contaminants and moisture rusted, scratched, and scored the bearing races. This kind of damage may be prevented by using the correct lubricant, keeping the bearing clean while handling, and using new or undamaged seals.

This illustrates the effect of coarse abrasives on the bearing raceways. Although it is difficult to picture, the dull gray discoloration on the raceway surfaces contrasts with the bright finish of a new bearing.

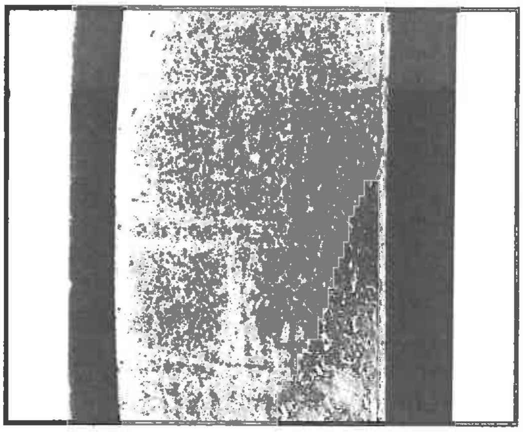


Foreign material caused excessive wear to these bearings. The roller ends are worn down to the indent and the ribs are badly worn.

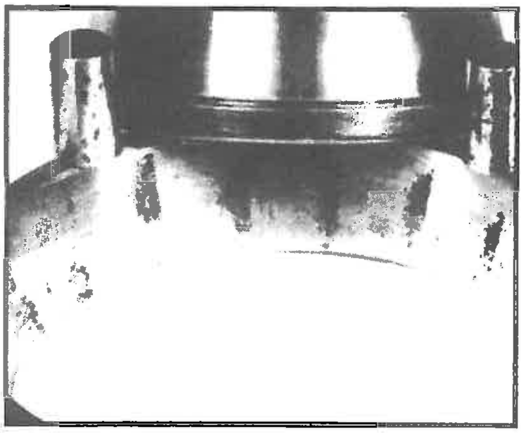


The second type of damage caused by foreign material is pitting. Pitting is a type of fatigue failure and appears when small particles of the bearing separate from the surface. As surfaces of mating parts come in contact, repeated stress on these surfaces can cause pitting.

Metal chips or large particles of dirt remaining in improperly cleaned housings are the most usual causes of trouble.

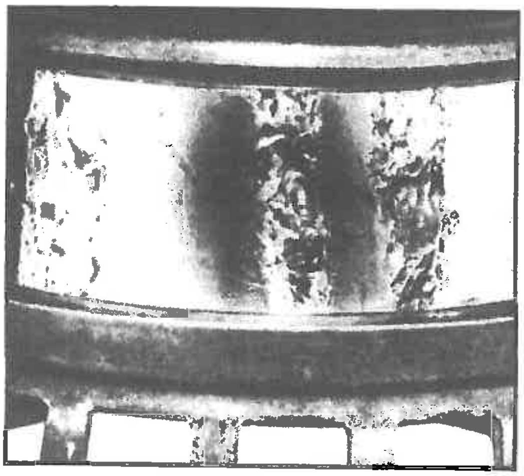


Fairly large particles of metal or dirt bruised and pitted the bearing race. Some of the indentations are so deep that the hardened surface of the bearing has fractured. The surface of the races would soon flake or spall (advanced pitting) with further operation of the bearing.



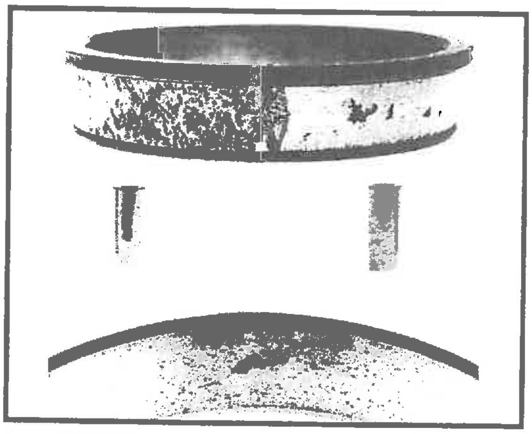
Rust or corrosion is a serious problem in antifriction bearings. The high degree of finish on races and rollers makes them quite susceptible to corrosion damage from water.

Corrosion is often caused by condensation in the bearing housing because of temperature changes. Moisture or water may get in through damaged, or worn seals. Considerable damage also results from improperly washing and drying bearings when they are removed for inspection.

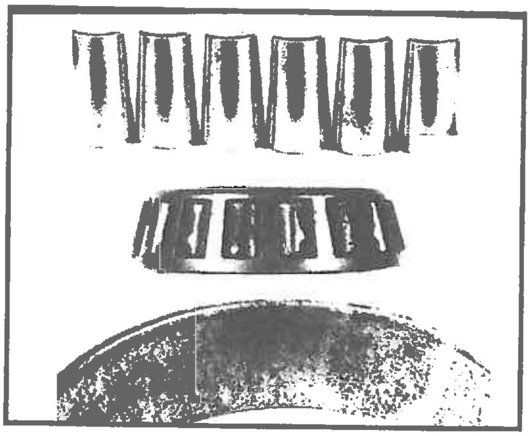


This shows more advanced damage from corrosion. The cones and the cups show spalling of the races at the areas where the heavy corrosion took place.

Advanced corrosion damage caused pits and spalls. Then as the metal continued to break down, as rollers hit the edges of the spalled areas, the complete raceway surfaces in the loaded area were broken down or spalled.

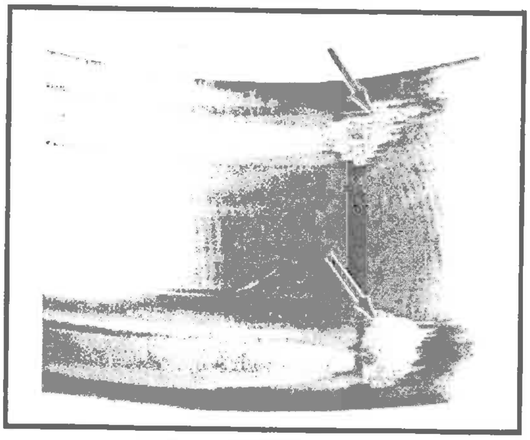


Water enters during unfavorable storage, through worn seals, or by leakage through gaskets or covers on housings. Results are heavy corrosion, or rusting.



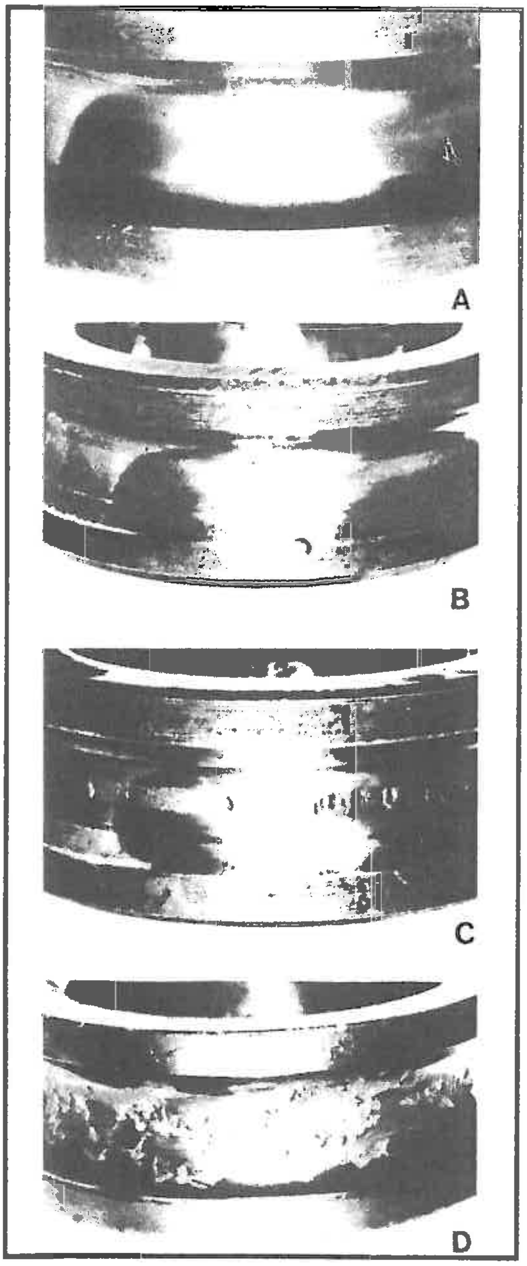
Improper Lubrication

Proper lubrication is important for a satisfactory bearing operation. It can be a complete lack of lubricant or too small a supply that causes bearings to fail. It may be the wrong kind of lubricant, or wrong grade or weight. Always use the specified lubricant.

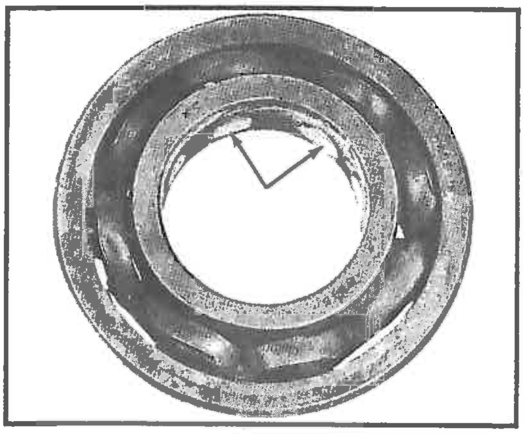


Too much lubricant that was too solid was used in the bearing. The rolling elements slide across the surface, rather than roll, smearing the metal. The thick lubricant slowed the rolling elements enough to start the sliding. As the metal surfaces became smeared, the rate of wear increased. This damage can also result from inadequate lubricant.

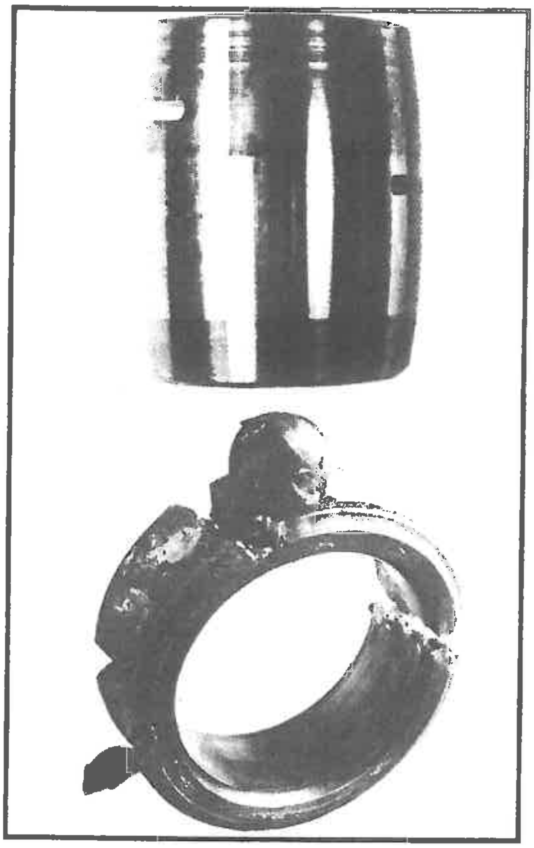
Another form of surface damage is progressively shown in A,B,C, and D. The first visible indication of trouble is usually a fine roughening of the surface. Later, spalling will begin from fine cracks.



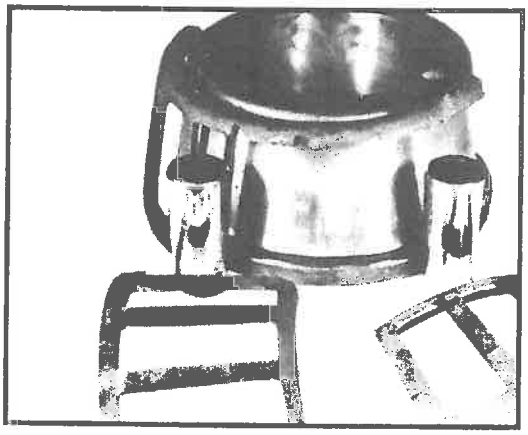
This shows discoloration of the bearing because of excessive heat.



A bearing may glaze (top) or balls may become welded to the ring (bottom).

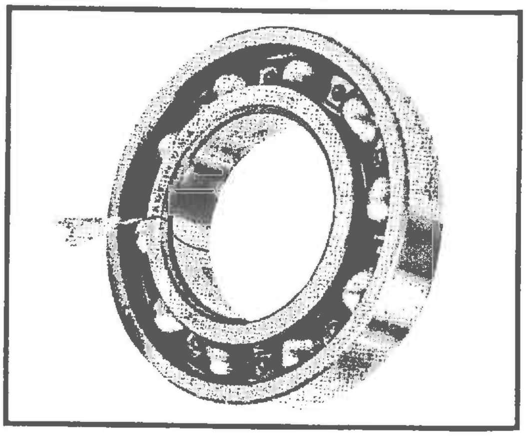


The broken cage was caused by intermittent lack of lubricant. At times, because of certain operation conditions, the oil fails to get to the bearing for a period long enough to cause light scoring of rollers and rib. This causes pressure on sides of cage pockets. After this has repeated a number of times, the cage finally starts to crack and then break up as shown.



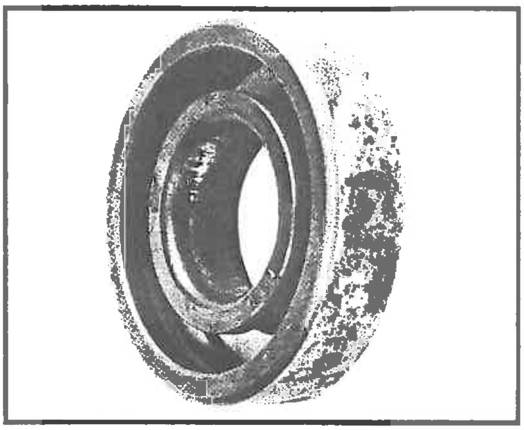
Improper Installation

Improper installation will also cause premature bearing failure. Excessive preload or tight adjustment can cause damage similar to inadequate lubrication damage. Frequently the two causes may be mixed so that a careful check is required to determine the real trouble.

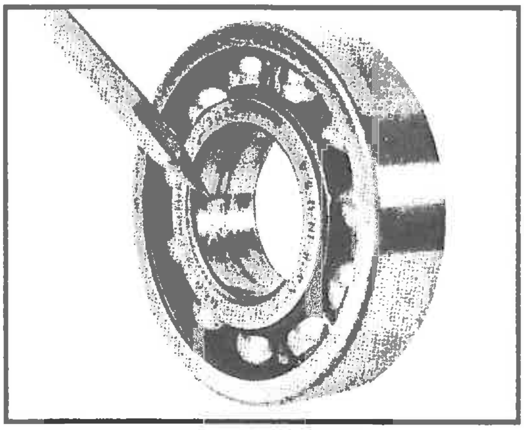


There are three types of damage resulting from improper installation. The first is a split race caused by forcing the bearing onto a shaft too large for the inside diameter of the bearing race.

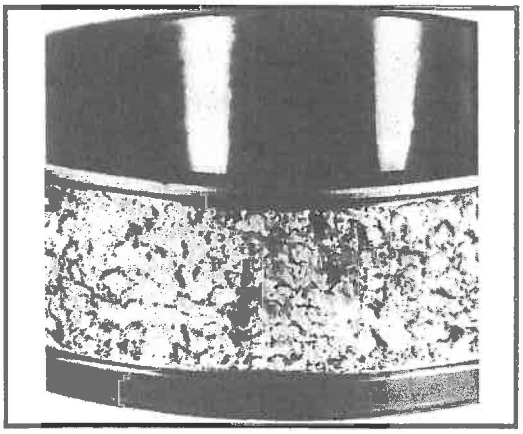
The outer race of a bearing damaged by "fit rust" or fretting corrosion, results when the outer race fits too loosely in its housing. Sanding or removing this rust will only increase the loose fit. The bearing must be replaced.



Creep wear is caused by too loose a fit between the shaft and the inside bore of the bearing. As this wear progresses, the inner race turns faster creating more friction and heat and leads to eventual failure.



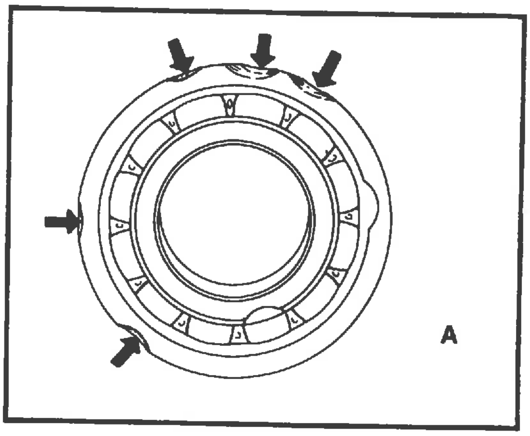
The bearing race is badly spalled from fatigue of metal. This fatigue occurred prematurely and could be eliminated by removing the preload or reducing it to the proper amount.

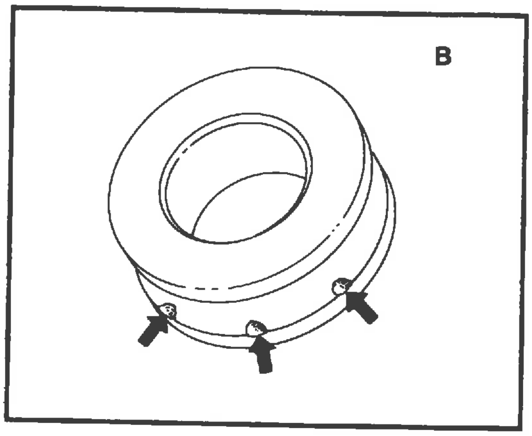


Careless Handling

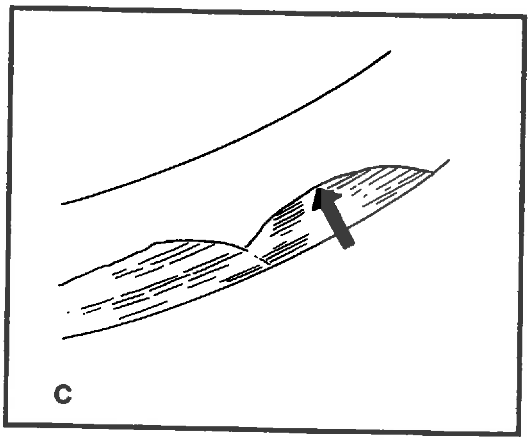
Bearing damage can be caused by careless handling, by improper service technique, and by use of improper tools during installation.

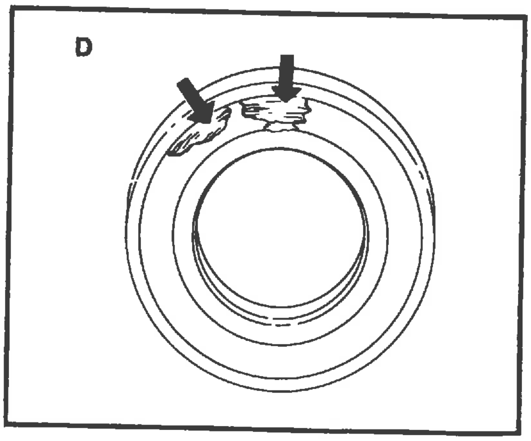
These bearings received improper service. Example A shows nicks in an outer race caused by using a hammering tool (drift) to drive the bearing. Example B is of cracks caused by striking the race with a hammer.



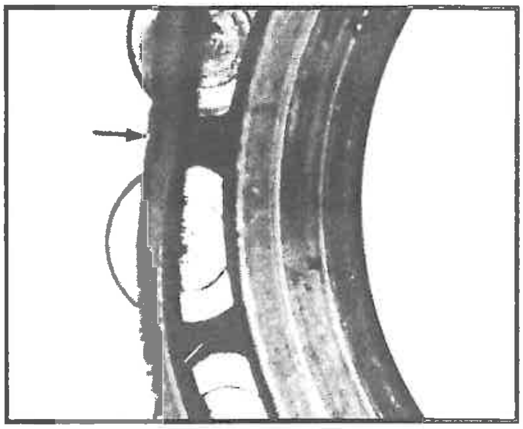


The results of the hammering also damages the inner race as shown in Example C. When the race is struck a severe blow, the force is transmitted through the rolling elements to the other race and chips it. Another result of using improper tools is a damaged seal on the sealed bearing in Example D. A drift slipped and gouged this seal. The seal's effectiveness is reduced and the separator is probably put in a bind.

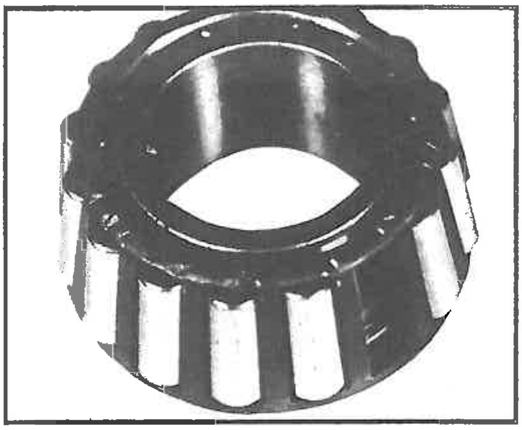




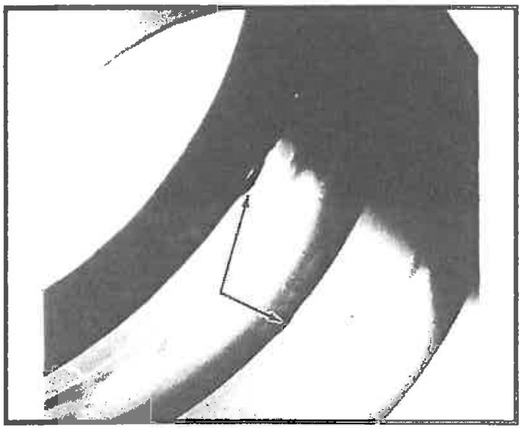
This bearing was dropped. It landed so that the cage was bent at the large end. This cage distortion causes the roller to bind in the cage and distort.



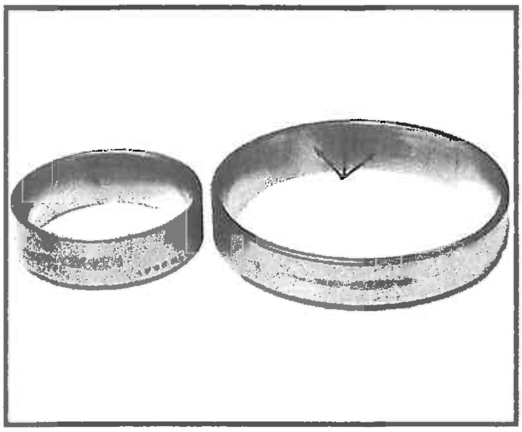
The cage was damaged during installation because proper tools were not used. It is apparent that a bar or drift was used against the cage instead of the cone face to drive the cone onto the shaft.

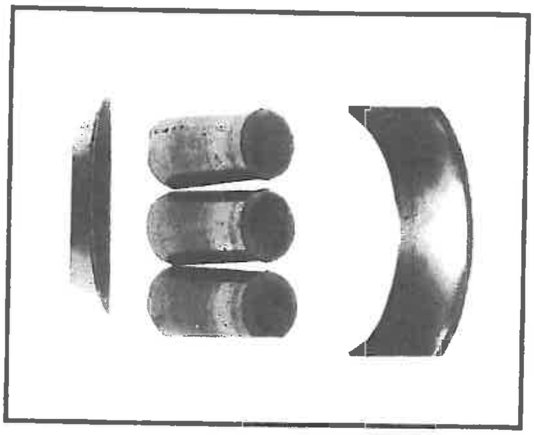


Fatigue damage was from an impact during either handling or mounting. An impact leaves a depression that can initiate premature fatigue.



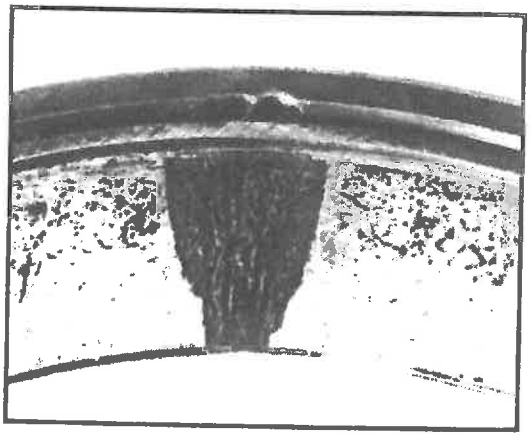
Nicks in cups were caused by the cone being in a cocked position with respect to the cup. The ends of some of the rollers dug into the cup surfaces. The roller edges were flattened and metal pushed up on the body of the rollers at these points. Because of the cocking action or tipping, the rollers were forced down on the edges of the cone race causing impressions at the extreme large and small ends of the cone raceway.



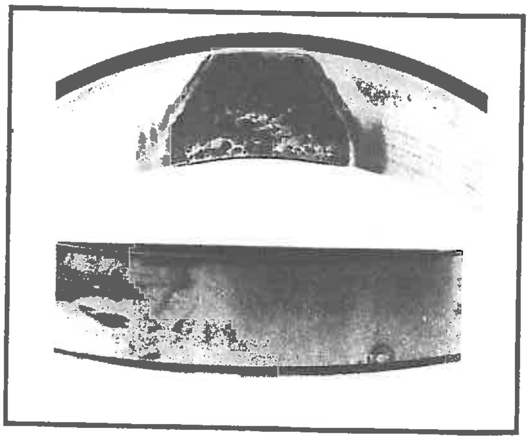


This shows how the bar or tool used to drive in the cup slipped and dug into the surface.

The marks extend out to the edge of the cup seat causing the high spot and the spall or fatigue at this point in the cup.

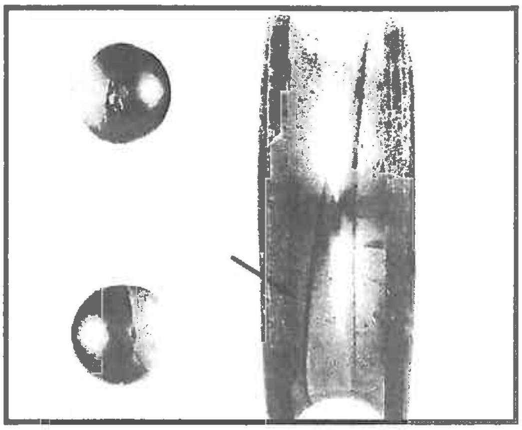


The inside diameter and outside diameter markings in the cup were caused by a high spot in the housing. The inside diameter is spalled at the area and the outside diameter shows heavy contact at the corresponding spot.

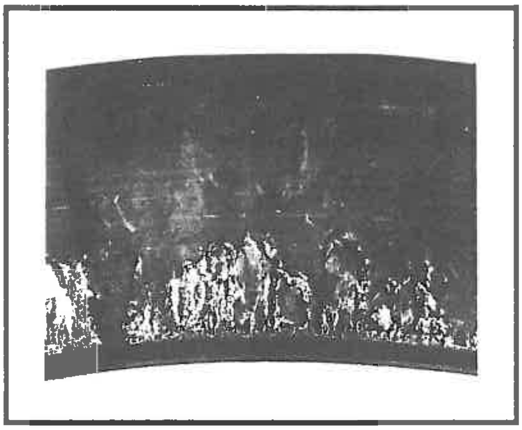


Misalignment

Misalignment is usually caused by a bent shaft, or foreign material between the bearing and its seat. Notice the paths worn in the races and the worn shape of the balls. Misalignment in roller or needle bearings usually results in extreme pressure on the races and rollers, and premature fatigue failure. The cause of failure must be determined and corrected or the same damage will result when new bearings are installed.



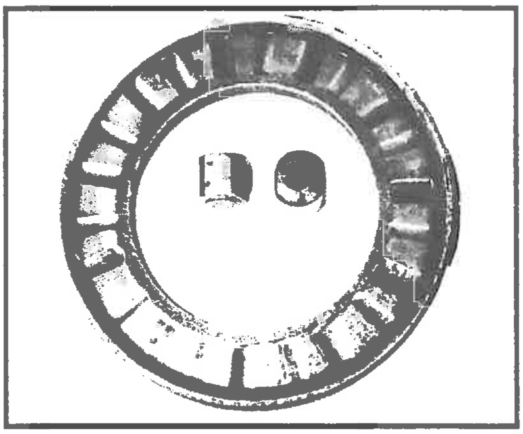
Excessive end play in a bearing resulted in this condition.



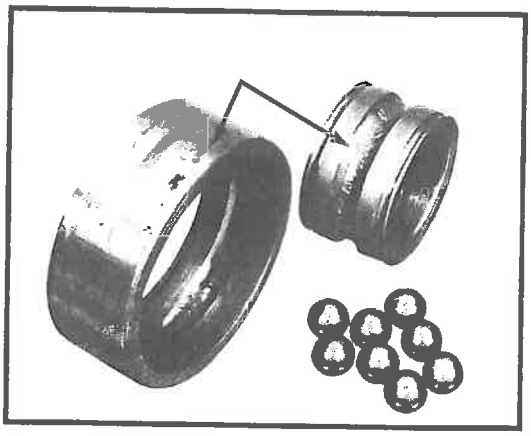
Severe Service

Extremely heavy impact loads of short durations can result in impressions in the bearing races and sometimes even fracturing the races and rollers.

If thrust bearings are set with end play, there is a pounding action set up as the wheel goes over uneven surfaces. These rapid short impacts pound the rollers onto the races and ultimately will fracture the race.

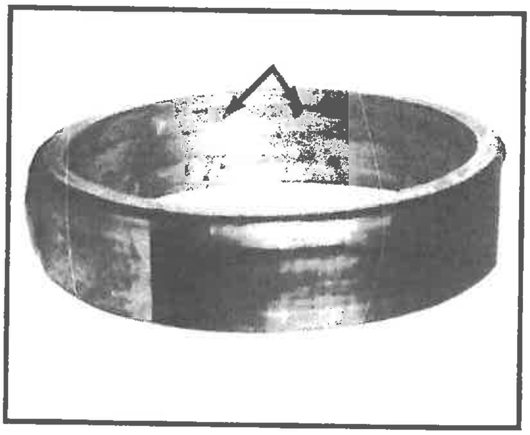


The first indications of fatigue failure may be noisy running and increased vibration. The bearing races show the metal surfaces of the races have flaked away. This flaking is caused by the effects of excessive speed and load.



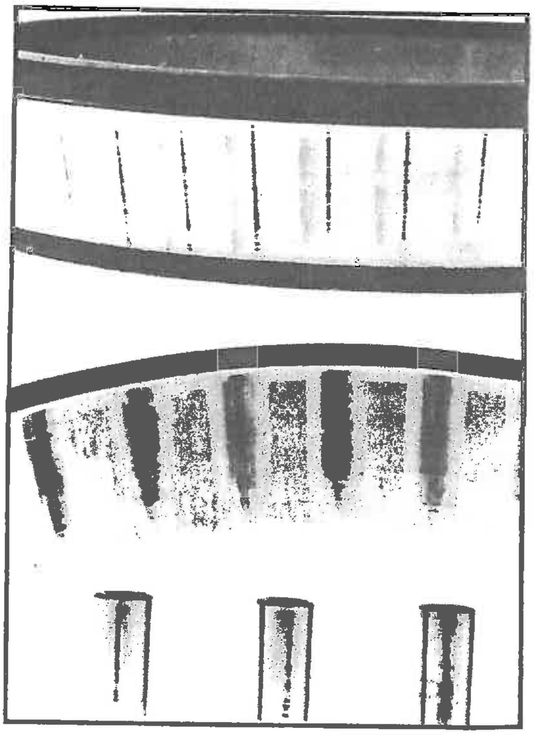
Vibration

Most antifriction bearings are rolling while under load. The bearing, however, was stationary while subjected to vibration. The depressions result from a combination of wear and impacts caused by this vibration. When this bearing is subjected to a rolling load, it will fail rapidly.



This wear is caused by the rollers sliding back and forth on the race while the bearing or race is stationary. A groove is worn into the race by this sliding of the roller back and forth across the race. Vibration causes the sliding movement. The vibration present may cause enough movement to produce some of this wear.

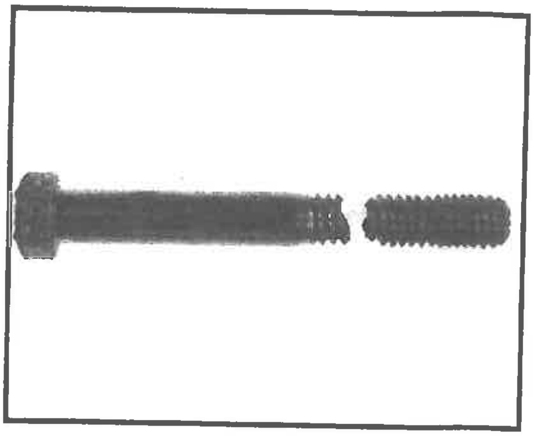
The heavier markings and particularly the deeper and sharper narrow groove will cause noise and roughness in the bearing.



BOLT & NUT FAILURES DURING ASSEMBLY

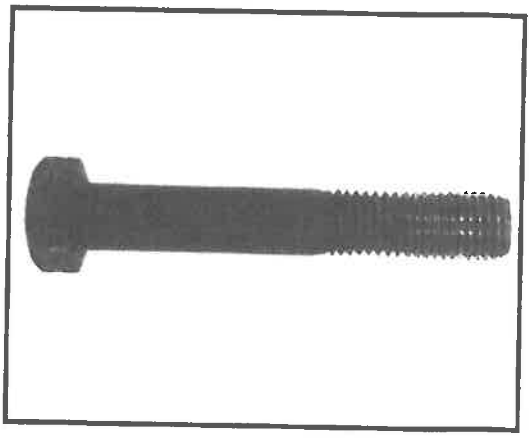
Bolt Twist Off

This bolt failure was from poor thread quality or a large friction factor between components.



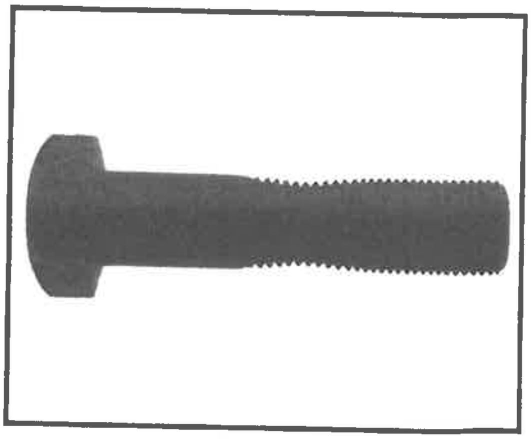
Galling

The deformed thread (galling) is due to poor thread contact with the nut.



Bolt Yield and Tensile Failure

Excessive torque cause this bolt to stretch and reduce the thickness of the threads. To prevent this from occurring, replace and reduce assembly torque.



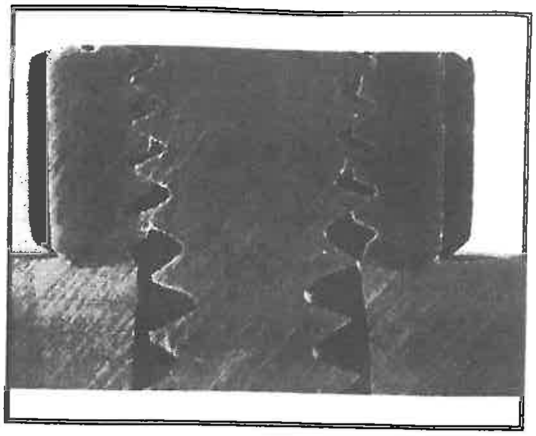
Fatigue Failure

These fasteners failed from a low bolt torque, or a combination of bolt torque and high cyclic stress. The service loads may have been higher than expected, or compounded by bending loads. Replace and use higher bolt torque. Replace with larger bolts. Reduce stress concentrations on the bolts.

Loss of Component Torque after Assembly

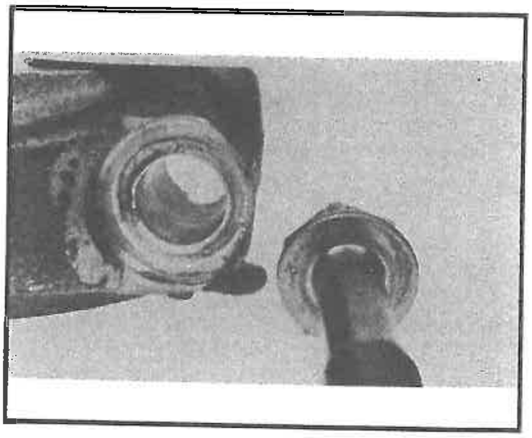
Dirty and rough surfaces can create vibration in the joint and cause self-loosening of the bolt. Clean surfaces to reduce contact stress. Use a locking device in the threads.

This shows fasteners with a higher strength than the components they are joining. The washer face of the nut is forced into the component surface. The hole in the component is deformed into the bolt. Replace with a flanged nut, add a hard washer, or increase the strength of the parts.



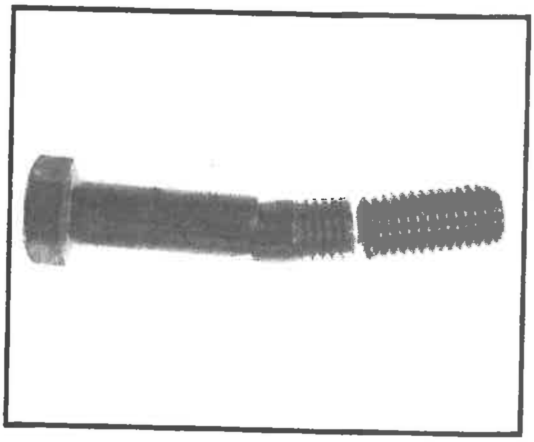
Galling

The galled surfaces of mating parts which rotate during assembly, are the result of poor surface finish or lack of lubricant. Improve surface finish, add lubricant, or change hardness of the surface.

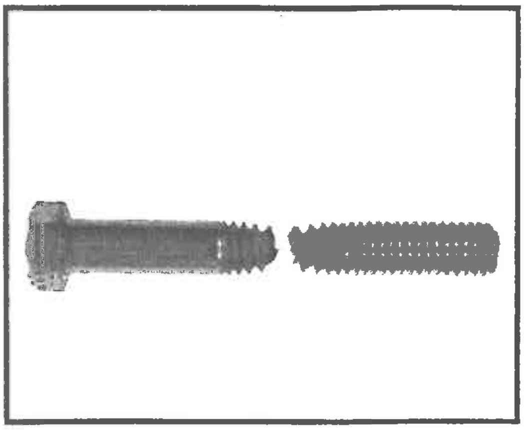


Shear Failure

This bolt indicates a large crosswise load was placed on the joint of the components. Replace and increase bolt torque. Use bushings to carry shear loads. Replace with a larger bolt.

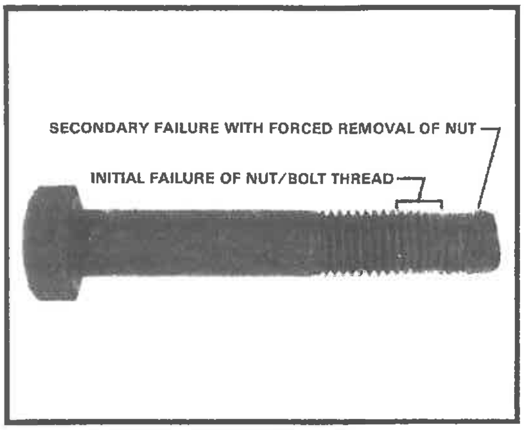


When friction is low, the recommended torque will produce too much tension on the bolt and cause this failure. Replace and reduce torque.



Nut/Bolt Failure

A bolt can be "stripped" by using a nut with short thread length, incorrect thread pitch, or incorrect hardness. Replace with a higher grade nut, or increase the nut height, making sure the thread pitch matches the bolt.



Nut Dilation

When a low grade nut is used in assembly, the washer face of the nut expands in diameter. Replace with higher strength nut, add a hard washer in joint or use a flanged nut.