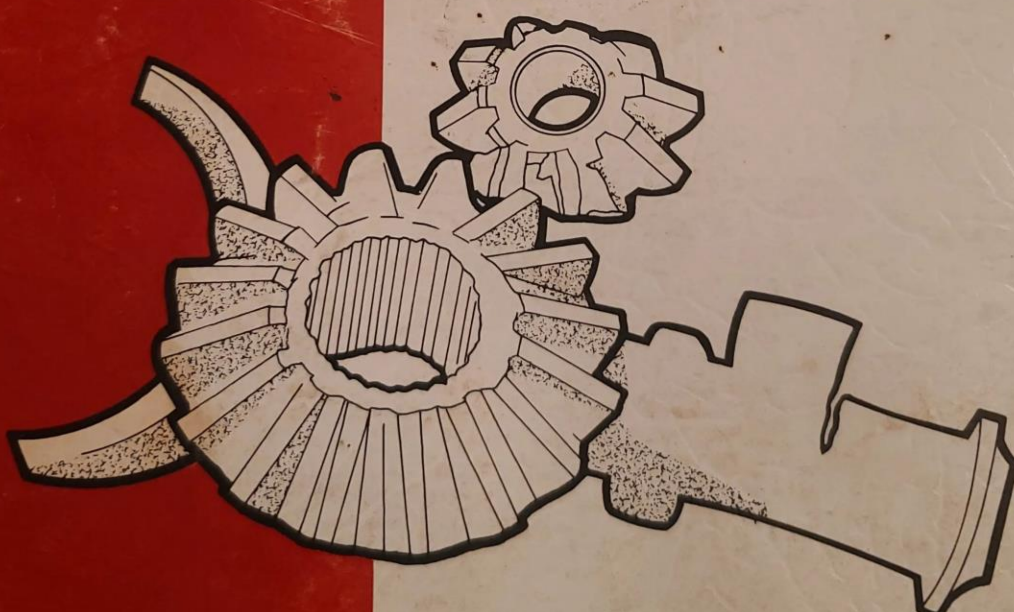
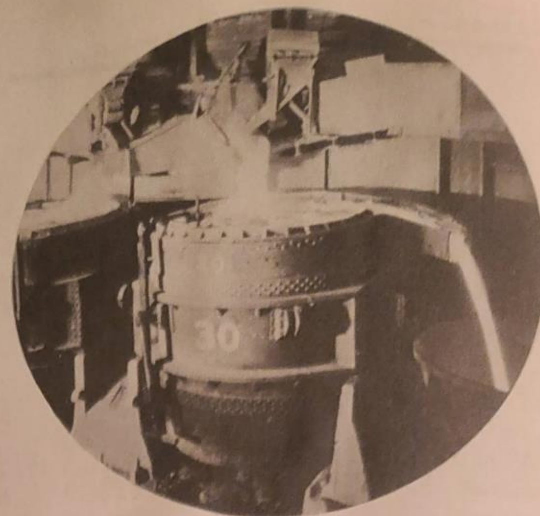
REMEMBER:

No one benefits when a damaged part goes on the scrap heap with the cause unknown.



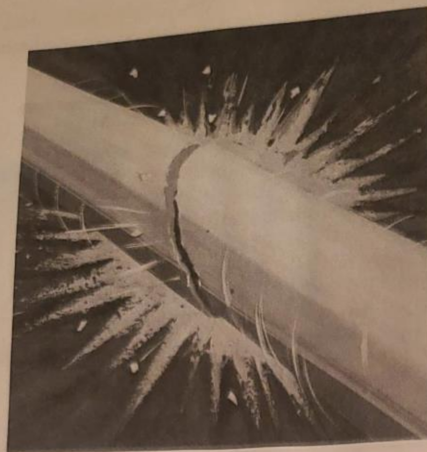
index

SUBJECT PAGE



steel:

The backbone of the automotive and trucking industry - has never been of higher quality than it is today. Manufacturing methods developed through a century of research have made the steel we now use vastly superior to that used in the past, with strength and durability that was once considered impossible. Yet, in the trucking industry, we know that even the highest grade of steel and other metals can only absorb so much punishment before reaching their...



breaking point:

The best way to ensure that the breaking point is never reached during the operation of a GMC Truck, is to operate the truck in a sensible manner within its rated capacity.

some of the common causes and types of failures

DRIVER ABUSE - including sloppy or improper shifting techniques, improper clutching, engine lugging or excessive speed over rough terrain.

OVERLOADING - an axle or suspension designed to carry 15,000 lbs. cannot be expected to carry 25,000 lbs. without serious consequences.

POOR MAINTENANCE OR SERVICE - moving parts need lubrication and/or periodic adjustments to function properly. Lack of either can result in abnormal wear.

EXAMINATION PROCEDURE - can help you determine which of these factors caused a failure in a given truck. It will reveal the nature of the failure, and whether or not the failure occurred all at once, or has been "building up" over a period of time. Let's take a look at how the examination is handled by looking at and discussing the various types of failures you may encounter in the field.

We will cover the following types of failures:

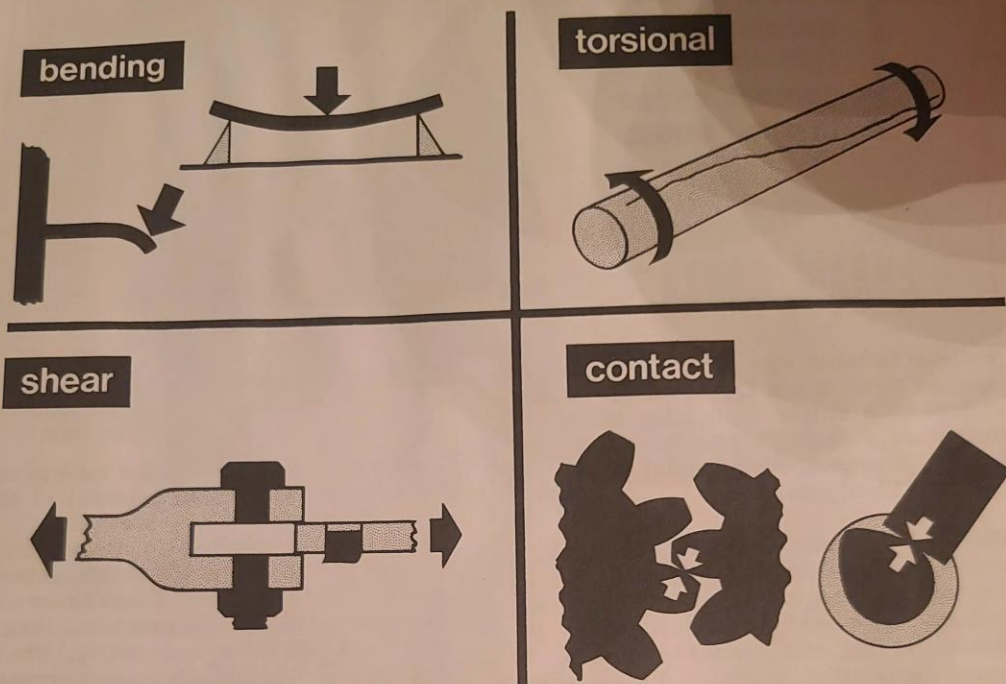
1. Fatigue
2. Impact shock
3. Abrasion
4. Corrosion

Each type has characteristics which in most cases will identify that particular failure.

We will begin by discussing fatigue failures, their causes and symptoms.

definition of terms

Arrows show application of force



EXAMINATION OF A FRACTURE MANY TIMES REVEALS A COMBINATION OF FAILURE TYPES. THIS WILL FREQUENTLY BE NOTICED IN THE EXAMINATION OF TRUCK FAILURES SINCE THE LOADS APPLIED TO A TRUCK COMPONENT WILL VARY GREATLY IN THE AMOUNT AND FREQUENCY OF FORCE, DIRECTION OF ROTATION AND THE VELOCITY.

1 fatigue failures

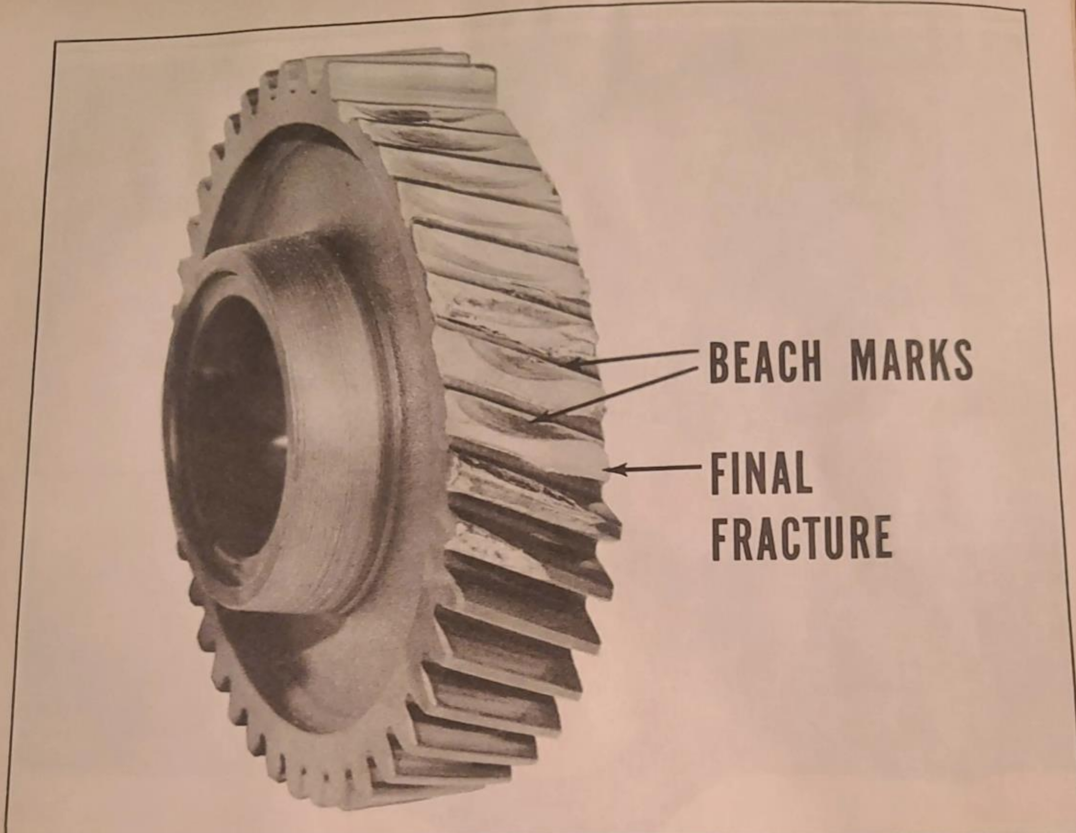
bending
torsional
contact stress
thermal stress

Fatigue failures commonly occur when the applied force is not large enough to cause failure by a single application of the load, but rather, repeated applications of the force gradually weaken the material to the point where it finally fails.

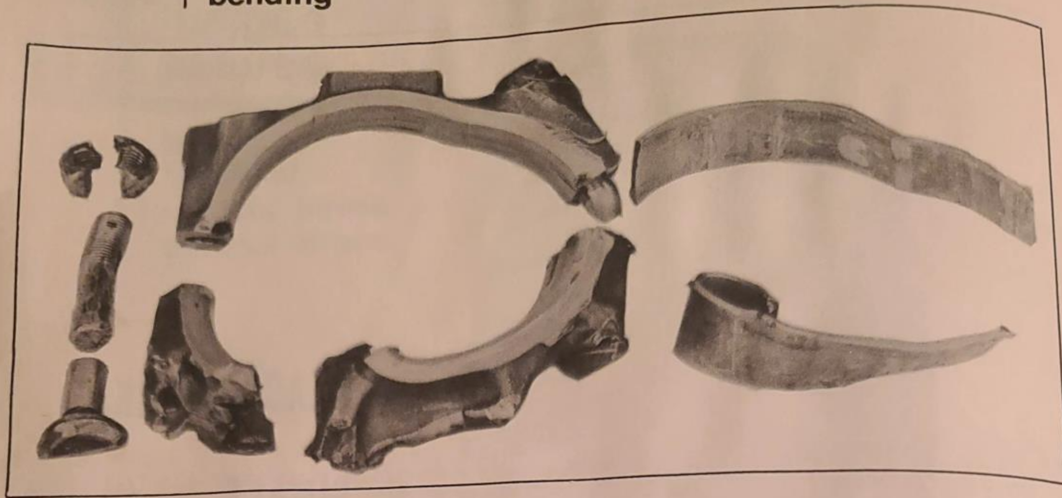
When a large enough force is applied to a metal so that deformation occurs due to a slip or rearrangement of the crystalline pattern, the metal will be weakened to a degree varying with the force applied. Repeated applications of such a force gradually reduce the strength of the metal until a microscopic stress crack develops at the point of greatest stress. This is the beginning of the phenomenon known as fatigue. As the application of force is repeated, the stress causes the crack to become larger. As the crack becomes larger, there is progressively less and less metal to withstand the stress until finally a fracture or separation occurs. Usually the final portion of the material to fracture will show impact or shock load fracture characteristics. Fatigue cracks require less and less force to perpetuate themselves as they become deeper, which is one reason fatigue failures are called "progressive" failures. Consequently, it is very often the case that the final fracture may occur with very little load.

Generally, the surface of the fatigue crack will be smooth and show a number of lines, marking the edges of the axial "steps". The lines are commonly called "beach marks" because they look like the beach marks left by flowing water on sand. These beach marks are produced by the progression of the crack from repeated opening and closing. The area of final failure is usually a rough crystalline surface, typical of an impact shock failure. It should be noted, however, that all fatigue failures don't exhibit the characteristic "beach marks".

In high strength metals, a smooth, bright area might indicate the origin of fatigue. The "beach marks" are then invisible to the naked eye, but closer examination by such instruments as a microscope or other magnification devices will sometimes reveal them. Since this type examination is usually impossible for a technician to accomplish, he should realize that the presence of such a bright, smooth area may be the indication of a fatigue-type failure in high strength metals.

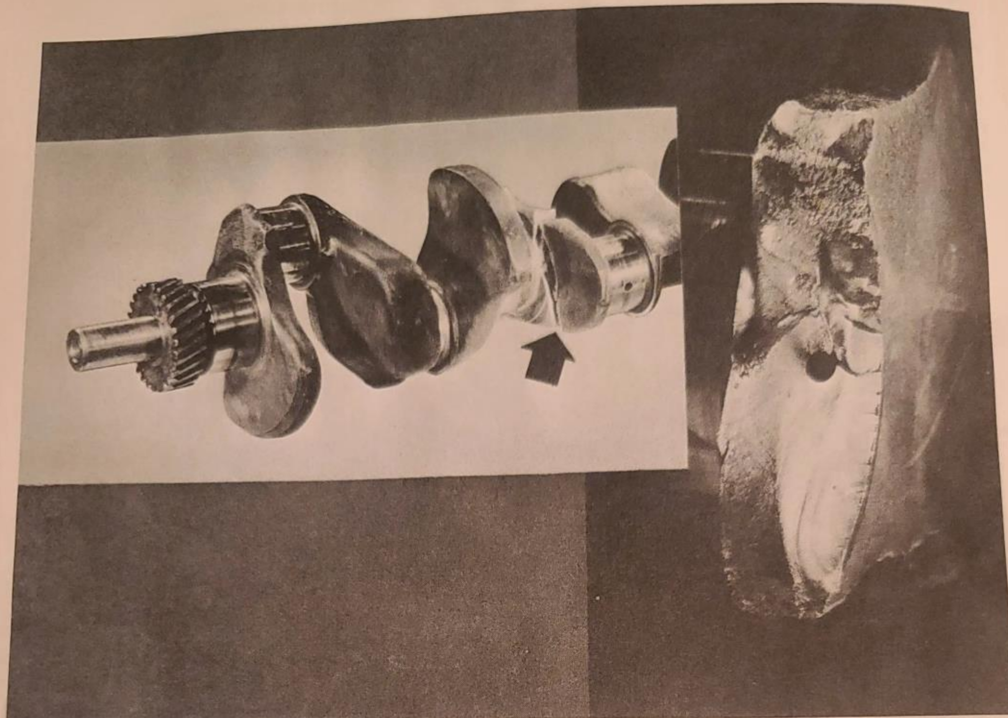


A bending fatigue failure usually is the result of continued working of the material brought about by conditions such as excessive loading, bending, or misalignment. A fatigue failure will usually begin at the weakest surface point, such as a burr, score mark or nick. The fatigue crack may progress until the material weakens and is unable to withstand the forces and stresses of the load. This will eventually result in a final failure. Generally, circular lines or "beach marks" will run across the fracture in bending fatigue.



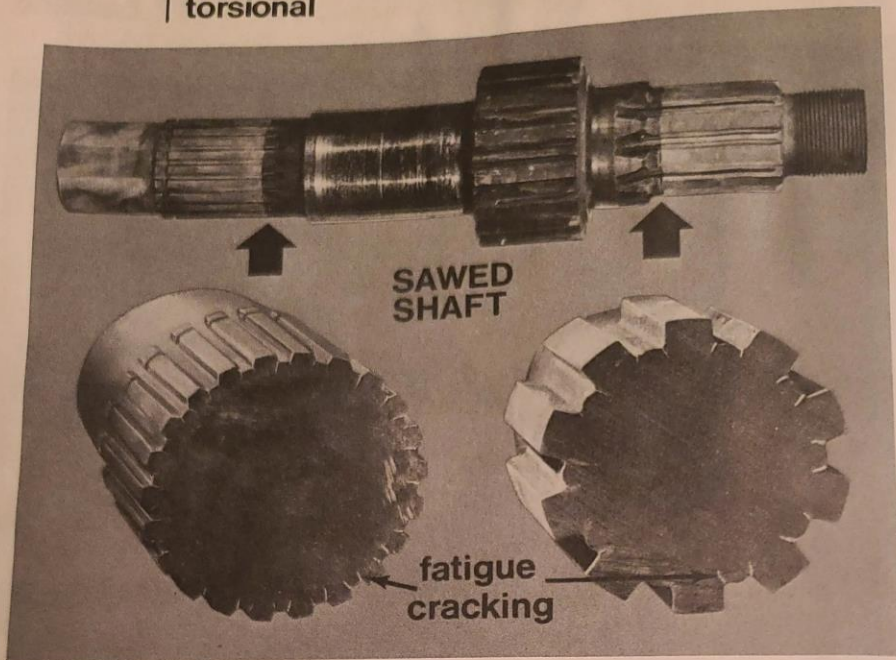
Damage to this connecting rod originated with the loose connecting rod bolt, indicated by the polished contact surface of the nut. As the bolt lost it's clamp load, the working action of the rod cap caused fatigue to set in. Although the outer surface of the bolt was battered in the final failure, you can still see the progress of the bending fatigue indicated by the characteristic beach marks across the core of the bolt.

The broken pieces of the connecting rod indicate impact/shock type fractures made after the bolt failed and allowed the rod to strike the other engine parts.



In rotating components, a misalignment or a loose bearing which allows misalignment will many times cause bending fatigue failures.

An actual bending or flexing of the component will take place at the point of misalignment with the resultant failure appearing identical to bending fatigue found in stationary components. In most failures of this type the point of origination will generally be found at a fillet, keyway, or drilled hole, as were the fatigue cracks in this crankshaft.



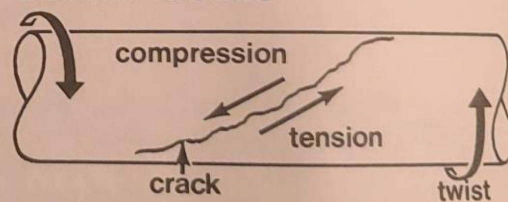
In components that carry a twisting type load or stress, progressive type failures are referred to as "Torsional Fatigue" failures.

Torsional fatigue failures result from a series of twisting or wrapping forces greater than the designed strength of the material. Transmission shafts, axle shafts, drive lines or torsion bars are typical components in which this type of failure is generally encountered. As a shaft is twisted it undergoes a fore/aft stress which, with excessive force, may progress to a separation of the metal causing a crack to start.

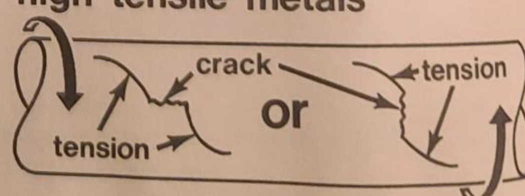
If keyways or splines are machined into a shaft torsional fatigue cracks will usually begin at the base of these splines or keyways and will progress working in towards the center of the shaft.

The start of torsional fatigue damage can be seen in the photo above of a transmission mainshaft which has been sawed through in two places.

ductile metals



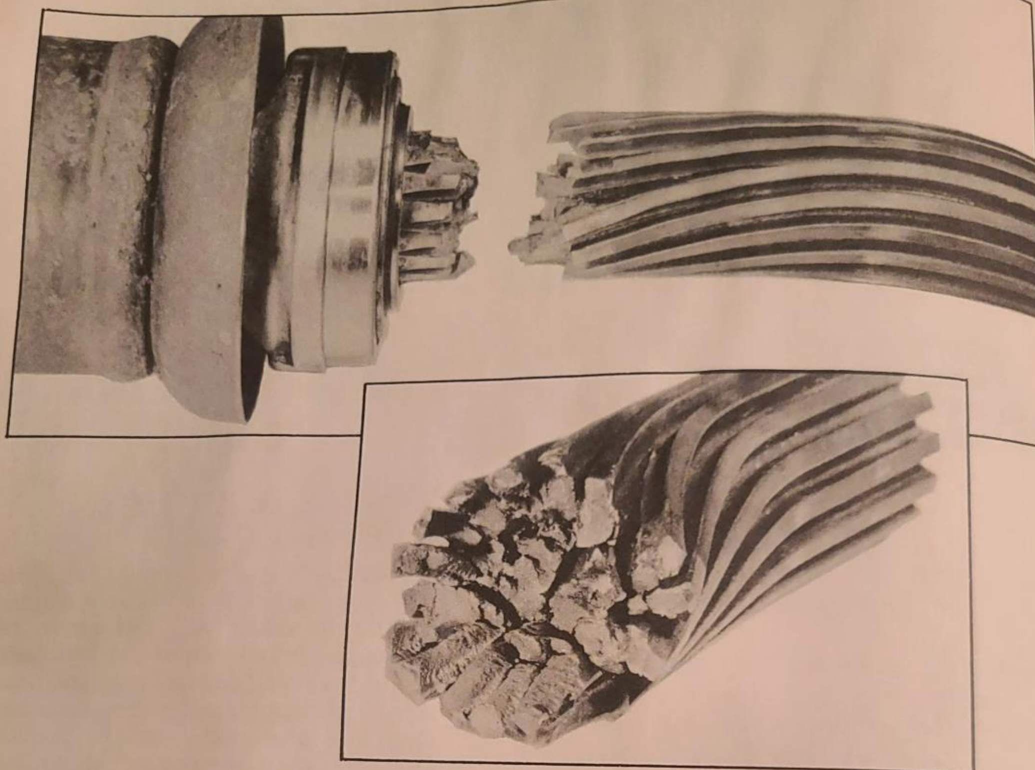
high tensile metals



In torsional fatigue damage, as the metal weakens from the cracks becoming longer and deeper, the weakened component becomes more susceptible to any impact/shock damage. Under these conditions the final failure may occur under medium to light application of load.

The axle shafts pictured here are both from the same truck. Shaft "A" is a good example of a torsional fatigue failure in an axle shaft. The arrow above shaft "B" points to a torsional fatigue crack.

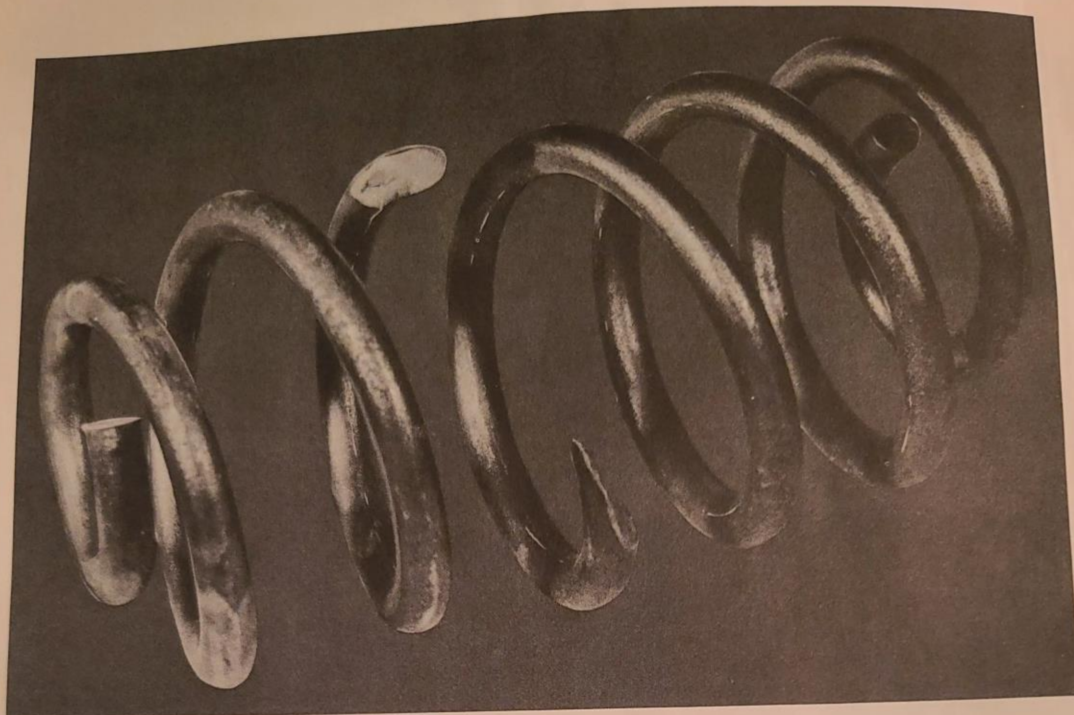
If put back into service, shaft "B" would probably fail very soon in a manner similar to shaft "A". Whenever replacing a broken axle shaft which failed due to torsional fatigue it is good practice to always inspect the opposite axle shaft for preliminary fatigue cracking along the shaft surface and at the base of the splines.



This stub shaft failure illustrates how torsional fatigue cracks start at the base of the splines and work in towards the center of the shaft at the same time spreading along the shafts. The broken end surfaces reflect typical impact/shock breakage characteristics.

Because of the weakness imposed by these cracks this shaft probably broke off under a slight shock to the drive line. If the fatigue damage had not been present the amount of torque which broke this shaft probably wouldn't have caused any damage.

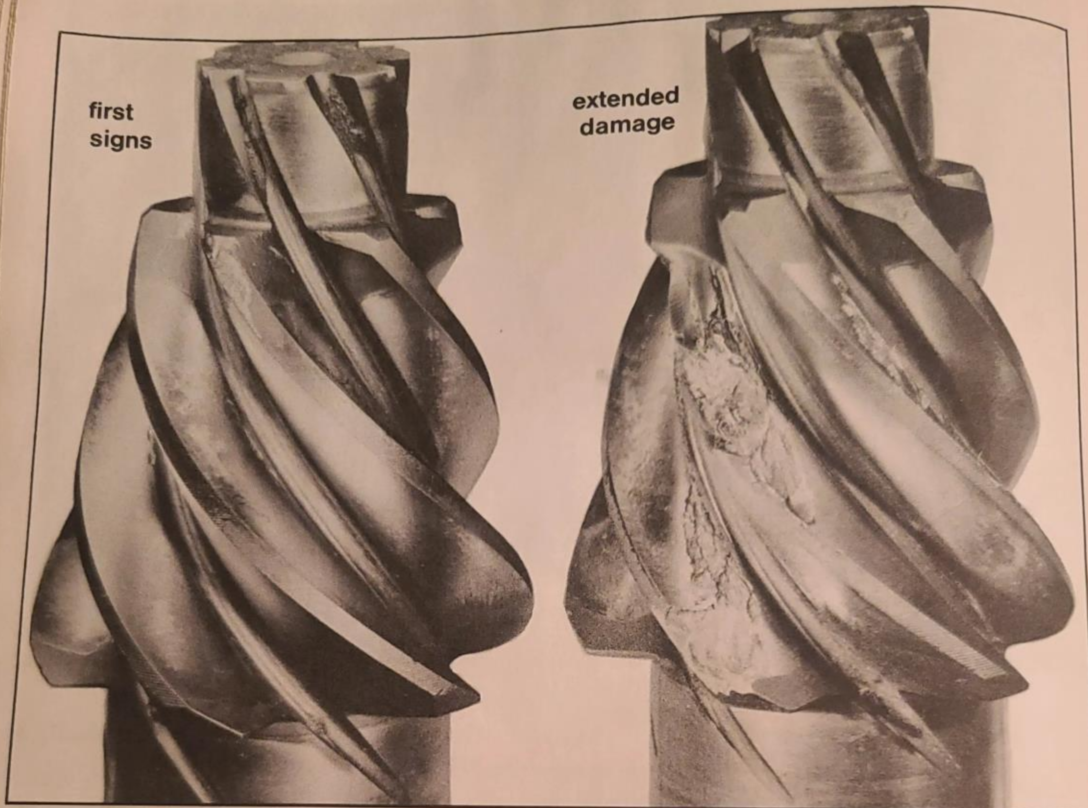
This torsional fatigue failure is commonly experienced in trucks which regularly carry loads in excess of their vehicle GVW or GCW ratings.



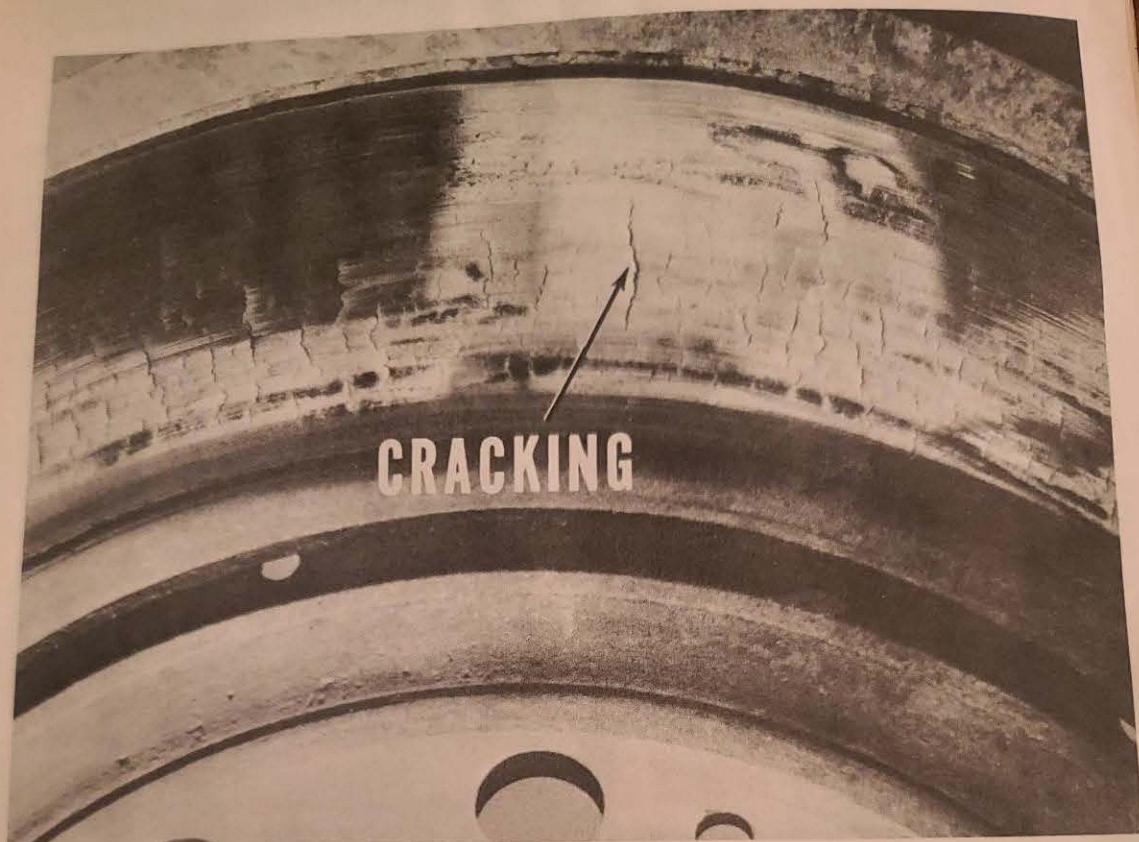
Breakage of coil springs is usually a torsional fatigue type failure.

This breakage is many times the result of operating an overloaded truck at high speeds over rough roads. Like the progressive weakening of fatigued components, the final failure may occur without load and at slow speeds over relatively smooth roads.

Note: Surface seams and pitting contribute to this type of failure usually at low mileage.



The surface damage to the teeth of these two pinion gears is typical of contact stress. Contact stress may take place when gear teeth such as these receive repeated overloading. The flexing imposed by the load working across the tooth surface eventually cracks and breaks away the surface areas. This damage may originate with a shock to the gears, such as "bucking" to start an overload, or frogging to pull out of a bad spot, which cracks the tooth surfaces. The damaging side effect to this type of damage is that the broken pieces can circulate through the rest of the gear assembly and cause considerable damage to bearings and other contact surfaces.



Thermal stress fatigue is another form of damage which normally occurs in brake drums, flywheel and clutch friction surfaces and other similar parts. This occurrence is also referred to as "heat checking" because the generation of heat is normally the cause of failure. Thermal stress fatigue develops in metal surfaces exposed to extreme pressure, and repeated heating and cooling cycles. The heat generated may cause surface cracking or even fracture. When heated, the surface layers expand; as they cool, they shrink. This cycling action can eventually cause the surfaces to crack. (Refer to example.)

summary outline

Summarizing, the primary conclusions which may be derived from analysis of fatigue type failures are as follows:

1. Repeated applications of force on a component result in stress cracks. The propagation of these cracks across the surface further weakens the material leading to eventual total failure of the component by fatigue, with either shock or torsion type final fractures.

2. Bending fatigue can occur in rotating and stationary components. The final fracture is usually of the shock load or impact type.

3. Torsional fatigue occurs primarily in rotating parts. The final fracture is of the torsion type. All other aspects of the fatigue cracks are the same as in bending fatigue.

4. Almost all fatigue failures have three basic failure characteristics; First, a relatively smooth surface which may have been battered smooth by the repeated opening and closing of the fatigue crack; second, a rough "crystalline" surface indicating the occurrence of the final fracture; and third, the radial lines or "beach marks" marking the edge of the axial "steps" in the surface formed as the fatigue "progresses" through the part.

5. Fatigue failures may be due to excessive loading, bending, or out of alignment conditions. Burrs, score marks, superficial cracks, or surface nicks can initiate fatigue failure.

6. Fatigue failures occur more often than any other type failure in heavy duty commercial vehicle operations.

7. "Beach marks" will generally run across the fracture section in bending fatigue or in a radial direction.

8. Fatigue fracture direction will generally be perpendicular to the axis of the failed component.

9. All fatigue failures do not exhibit the characteristic "beach marks". In high strength alloys, a smooth, bright area might indicate the origin of fatigue. The "beach marks" are invisible to the unaided eye but can be revealed by magnification devices.

material testing

Component parts which are suspected of having been subjected to excessive loads but in which no visible fatigue cracks can be seen may be tested to detect microscopic fatigue cracks. The common method is by magnetic partical inspection. The parts in question should be taken to a source with the necessary magnetic inspection equipment.

2 impact / shock load failures

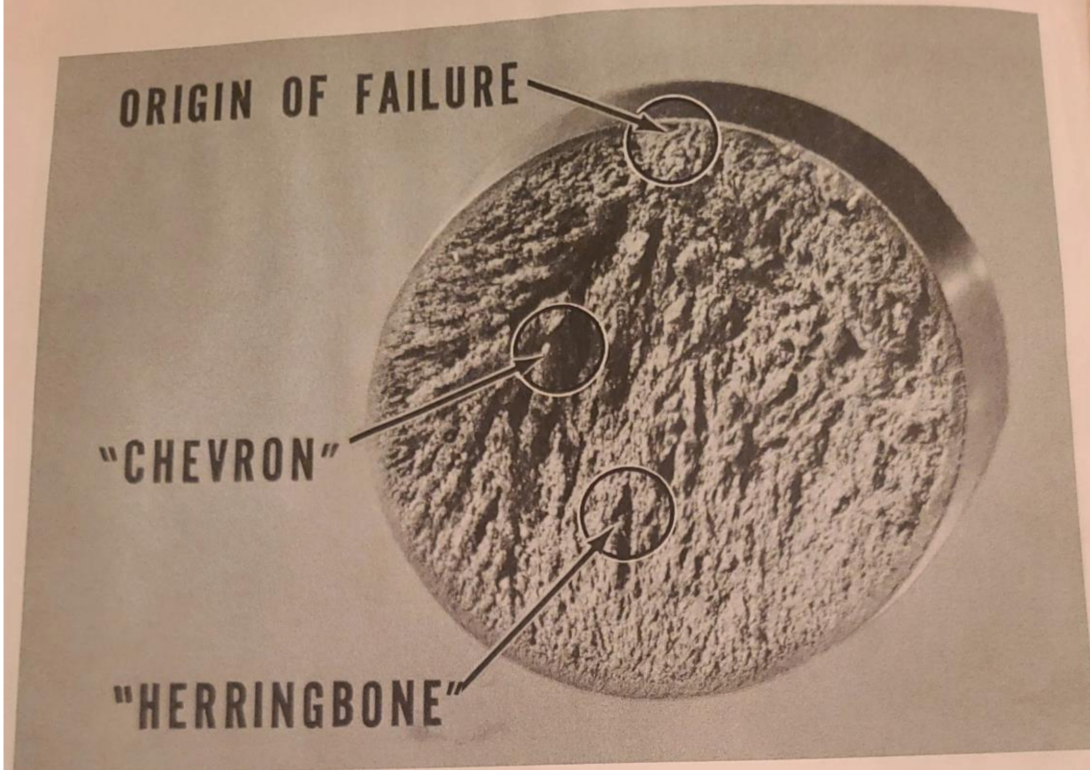
bending
torsional
shear

Impact/shock type failures are a sudden and complete fracture of parts. An impact/shock type failure is usually caused by a single, quickly applied, excessive load.

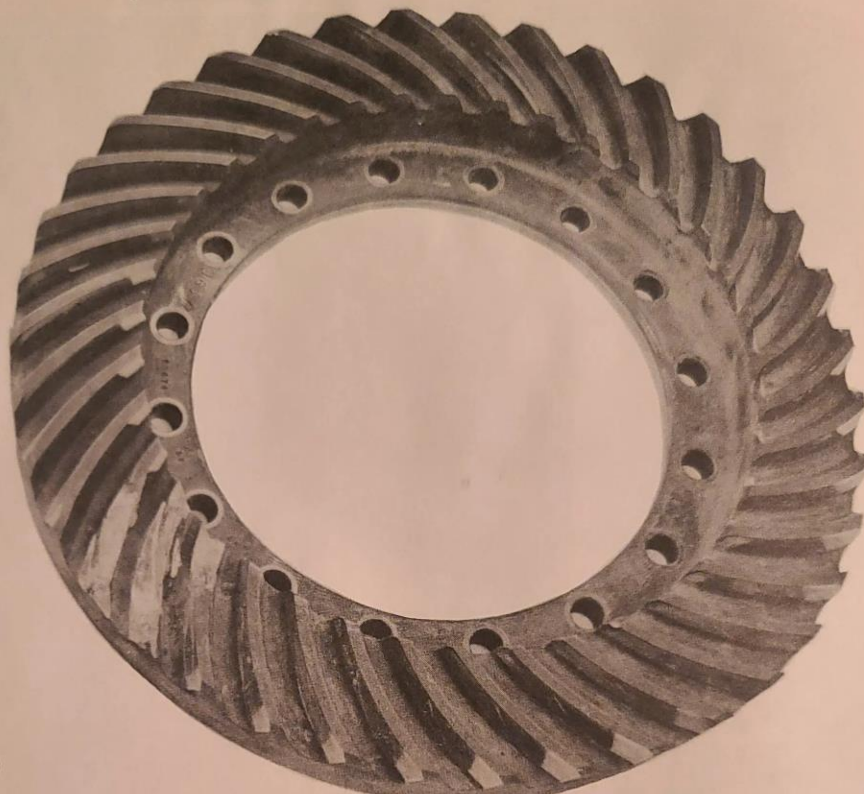
granular structure

True impact failures can be recognized by their granular structure. Since the failure is practically instantaneous in pure impact, fatigue lines or other cross sectional imperfections are usually absent. The failure in the photo above is an example of a bending-impact failure.

NOTE: Although this failure was initiated by fatigue, the characteristics of the failure exemplify what a typical impact failure looks like.



Impact failures often appear very bright and crystalline. When rotated in the hand, an impact fracture specimen will generally sparkle. The surface of brittle fractures have a distinctive appearance. A characteristic "chevron" or "herringbone" pattern is formed which points toward the fracture origin. It is usually necessary to have a strong light at a grazing angle to the fracture surface to illuminate these markings. It should be noted that, although both shear and impact fracture type exist, rarely do they occur alone. Many shock load failures will wipe their surfaces as the parts separate smearing the granular surface and appearing like a shear failure. The photo shows how a tough ductile material can fail as a result of an impact load.

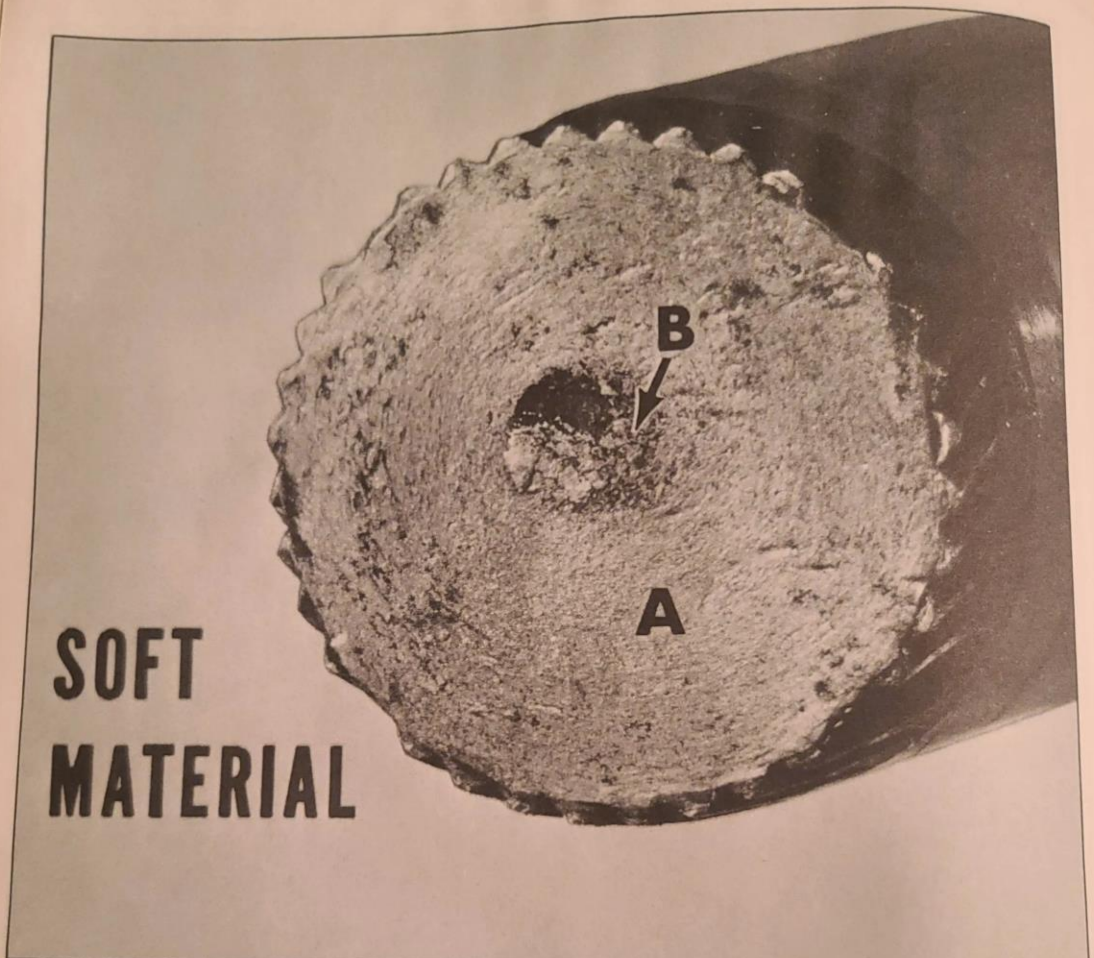


When a rear axle ring and pinion gear set are subjected to a shock loading the damage will many times look like that on the gear set pictured here.

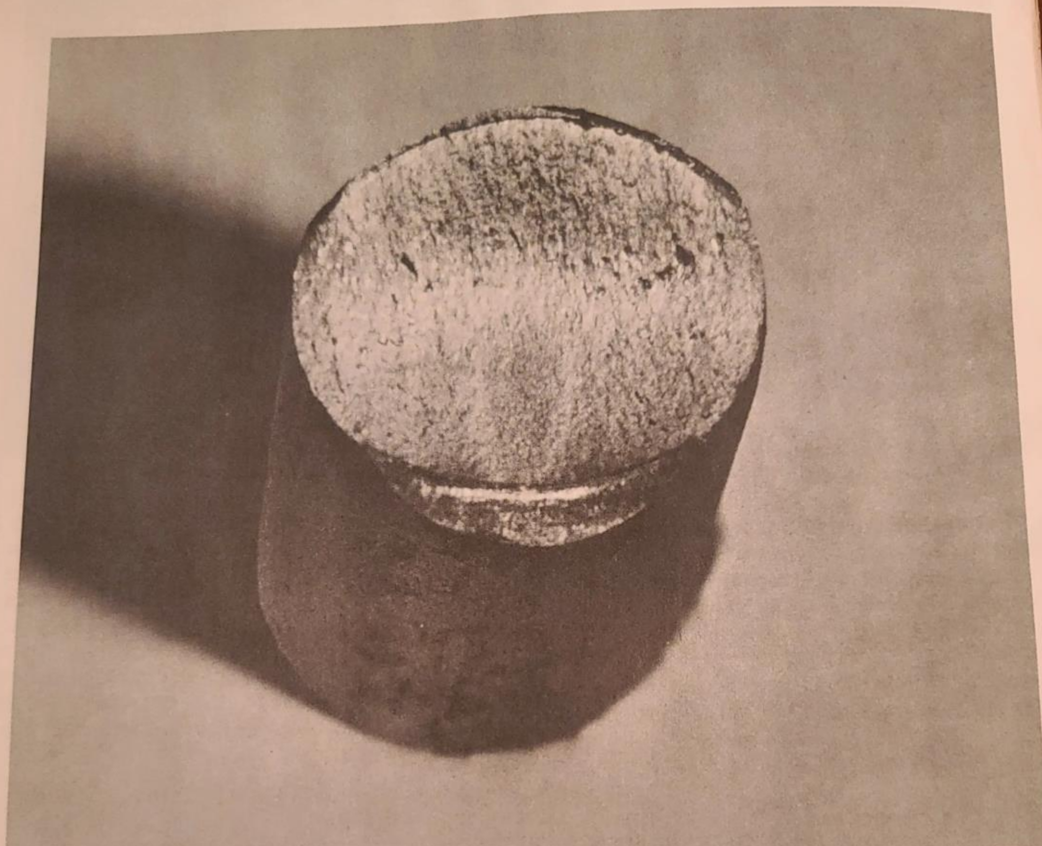
The tooth breakage on the ring gear occurred only at the place where the shock loading was imposed. The broken tooth surface shows the bright crystalline granular pattern typical of impact failures.

This damage is usually caused by improper driving techniques, such as bucking to start an overload or frogging to pull out of a bad spot in the road.

In a harder material such as the steel in this axle shaft, the torsional impact fracture usually occurs at an angle to the axis of the part and has a crystalline, jagged appearance. The arrow indicates the direction of rotation of the shaft. Poor operating practices are the usual cause of such a failure as this.



When excessive torque or twist is applied to a part - a torsional impact failure may occur. This can be depicted by imagining a rotating shaft that is seized and held immovable while the rotating force continues to act. In softer materials the torsional impact fracture looks like a bending impact fracture in that the shaft usually breaks perpendicular to the axis of the part. (See photo above.) The failure can be distinguished from bending impact by the smeared circular appearance of the fractured surface ("A" on photo) and a nipple usually located near the center of the part which indicates the final failure area ("B" on photo).



shear fractures

Shear fractures may be compared to the separation of a deck of cards when one part of the deck slides over the other until translation separates the deck into two stacks.

impact failures are not a cause they are a RESULT!

It is important that, when indications of impact failure are present, caution be exercised in determining the primary cause of failure. Although impact is present in many failures, often it is not the primary cause but only the final result. -The importance of determining the primary cause of failure by complete and comprehensive analysis of all factors involved cannot be overemphasized. Accidents would be a good source of complete impact type failures. These failures are sometimes identified by an external marking showing that an outside force has caused the failure.

summary outline

The primary conclusions which may be derived from analysis of impact type failures are as follows:

1. Impact or shock fractures are frequently associated with overload operating conditions. True impact fractures are caused by an extremely high and rapid rate of loading.

2. The three distinct types of shock load fractures are shear, impact, and torsional.

3. The final failure of a part is often due to impact because the weakening of the material by other processes causes complete failure with a very small force.

4. Shear type impact failures are found in very ductile material which deform plastically when a sudden, excessive force is applied.

5. Shock-Impact failures are found in both brittle and ductile materials and appear very bright and crystalline. The characteristic "Herringbone" or "Chevron" markings are usually present.

6. Very few shock impact failures will be either shear or impact type but usually a combination of the two due to the differences in stress and the orientation of crystal planes within the part.

7. Chipping type impact failures occur when covers of very hard, brittle parts are struck or loaded repeatedly by other components with hard surfaces. Fragments chip off, such as on hardened gear teeth.

8. Accidents are a cause of purely impact type failures due to the extremely high loading possible due to inertia of the moving vehicle.

3 abrasive failures

Abrasive wear occurs when hard particles slide or roll under pressure across a surface or when one surface rubs against another. Most failures due to surface damage (except for corrosion) may be classified as some form of abrasion. There are many types of abrasion failures, such as scuffing, scoring, adhesion, fretting, ridging, etc. This section will discuss some of the more prevalent forms of abrasion since there is little variation among other types.

Abrasion failures are most generally caused by insufficient clearance between working parts, lack of lubrication, or the presence of foreign matter. An abrasion failure can usually be identified by:

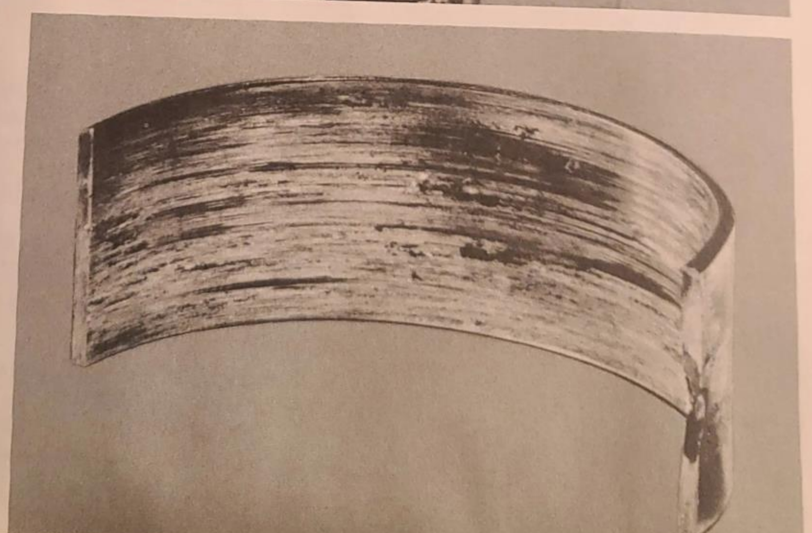
1. Discoloration of the wearing or worn part due to heat generated by friction.

2. Presence of material, chips, etc. from adjacent members.

3. Grooves in the wearing surface in the direction of movement.


GROOVES
DISCOLORATION
(HEAT)


METAL
TEARS



abrasion

True abrasion is usually associated with the presence of foreign matter (refer to photo at left) which causes grooving and chipping. Metal to metal contact and transfer between adjacent parts, on the other hand, is usually classified as adhesion.

adhesion

Adhesion, (also called scoring, scuffing, galling, and seizing) results when microscopic projections at the sliding interface between two parts weld together under extreme temperature and pressure.

After welding occurs, sliding forces tear the metal and cause the transfer of metal from one surface to the other. (See photo at left center.) Adhesion can be eliminated only by preventing absolute metal to metal contact. When tightly adhering surface films separate the two metals, adhesive wear does not occur. If necessary, extreme pressure lubricants should be used. These lubricants react chemically with the surfaces, providing sufficient lubrication to prevent welding. Because heat is developed during adhesive wear, care must be taken to keep the interface temperatures below the lubricant critical temperature. Surfaces that are extremely rough or very smooth are more apt to score than surfaces which are nearly smooth. The latter lack large projections, but have minute reservoirs which retain lubricant.

recording surface damage

A very simple method has been devised for recording surface damage such as pitting, scoring, and wear. It is possible to record replicas of entire cylindrical surfaces or many teeth of a gear on a single sheet of paper. During testing, this method can also be used to record progress intervals of damage. An outline of the procedure follows:

1. The surface is cleaned, leaving a light film of oil.

2. The surface to be reproduced is lightly brushed with a fine dark powder such as graphite. Any excess powder should be brushed off with a soft camel's hair brush or soft tissue.

3. Pressure - sensitive transparent tape should be applied adhesive side down, to the surface to be examined. The tape should be rubbed with a pencil or fingers so that it adheres to the surface.

4. The tape should be removed and applied to a sheet of white paper or a glass slide, which will permanently record the surface appearance.

summary outline

Listed below are conclusions which may be derived from the analysis of abrasion and adhesion failures.

1. Abrasion failures are most generally caused by insufficient clearance between working parts, lack of lubrication, or the presence of foreign matter.

2. Abrasion failures can be identified by discoloration of the part due to heat, presence of material or chips from adjacent members and grooves in the wearing surface in the direction of movement.

3. Abrasion is usually associated with the presence of foreign material while adhesion results from the metal to metal contact between two mating surfaces causing the surfaces to weld together under extreme temperature and pressure.

4. Adhesion may generally be prevented by the use of proper extreme pressure lubricants.

5. Contact stress fatigue, a cause of abrasive wear, is caused by small cavitities forming in the surface due to contact with other parts. This causes deterioration of the surface and the lubricant sometimes carries hard metal particles to other locations leading to further damage.

6. Contact stress fatigue may be prevented by avoiding concentrated loading on the part, increasing in unison hardness and smoothness of the surface and using steels relatively free of non - metallic inclusions.

7. Thermal stress fatigue ("heat checking"), another form of surface damage, develops in metal surfaces sliding under pressure or parts subjected to repeated heating and cooling cycles.

4 corrosion failures

Corrosion is defined as the deterioration of a substance (usually a metal) or its properties because of a reaction in its environment. There are various types of corrosion. Action of these various types can cause components to fail in service. A thorough knowledge of corrosion characteristics is essential because corrosion effects have been known to complicate the analysis of service failures. It should be pointed out that there is more than one type of corrosion - in fact, there are six distinct forms of corrosion.

These are uniform corrosion, galvanic corrosion, fretting corrosion, high temperature corrosion, stress corrosion and cavitation erosion. All types are equally damaging to components but are the result of varying circumstances. Each of the six types will be explained as to cause, appearance, and methods of prevention. Also, conclusions derived from the three explanations will be stated.

uniform corrosion

The most common type of corrosion, uniform corrosion, develops rather evenly over entire exposed surfaces of unprotected objects. It is caused by simple chemical action (usually oxidation) between a metal and its environment. An example would be the general rusting of unprotected truck sheet metal or truck wheels.

This type of corrosion destroys the greatest amount of metal. From a technical standpoint, however, uniform corrosion is not very serious. The life of components can be fairly well predicted by simple exposure or immersion tests at the factory. If some form of protection is needed, economic factors govern the choice of metal, inhibitors, protective coatings or combinations of these.

galvanic corrosion

The second type, galvanic corrosion, is a very common type of corrosion which most often leads to metal failure. In order for galvanic corrosion to occur, two factors must be present. These are:

1. A combination of dissimilar metals.
2. A means of electrical connection, an electrolyte, between the metals.

Dissimilar metals are metals differing in molecular structure and/or electro potential such as cast iron and aluminum. The "galvanic series" is usually employed to show the tendency of various combinations of metals to corrode when electrically coupled. In this series, several common metals and alloys are arranged so that, of any given pair, the lower on the list forms the cathode and the higher, the anode. If two metals are close together in the series, a small current is generated and corrosion on the anode will be slight. However, with metals widely separated in the series, the anode or upper metal will corrode considerably provided an electrolyte is present to complete the circuit. This is due to the two different metals forming an electrical cell or battery which generates the necessary current through the electrolyte to assist the corrosion process.

The appearance of galvanic corrosion is much the same as uniform corrosion and generally appears in the form of an active eating away of softer materials such as aluminum or cast iron or pitting marks on hardened or highly finished material, such as piston pins, crankshafts, and other similar materials.

A single piece of metal can also provide the requirements for galvanic corrosion if its structure is changed due to rearrangement of the grains of which it is composed. A typical example of this is a bent nail. The structure of the metal in the bent (stressed) area differs from that in the unbent portion due to the rearrangement of the grain pattern by the outside force. This single nail, therefore, provides the requirement of two dissimilar metals. The electrolyte in these galvanic cells may be any conducting liquid such as water, lubricant, or fuel. It is not essential that the electrolyte be in the liquid state to contribute to corrosion. The atmosphere usually contains enough moisture to act as an electrolyte and, thereby, fulfills the second condition required for galvanic corrosion.

There are three methods by which galvanic corrosion between two metals may be prevented:

1. The two metal sections should be electrically insulated from each other.

2. The component should be designed so that a small cathode (negative) area is joined to a large anodic (positive) area in the electrolyte. This tends to dissipate the current at the anode, preventing severe corrosion.

3. An expendable metal, one with no useful component function but located high in the galvanic series (such as magnesium or zinc) should be fastened in strategic locations to the metal to be protected. The expendable metal becomes the anode and corrodes while the steel remains free from corrosion.

GALVANIC SERIES

CORRODED OR ANODIC END

- MAGNESIUM
- MAGNESIUM ALLOYS
- ZINC
- ALUMINUM
- CADMIUM
- STEEL OR IRON
- CAST IRON
- STAINLESS STEELS (Active)
- LEAD
- TIN
- NICKEL (Active)
- BRASSES
- COPPER
- BRONZES
- COPPER - NICKEL ALLOYS
- MONEL
- NICKEL (Passive)
- STAINLESS STEELS (Passive)
- SILVER
- GRAPHITE
- GOLD

PROTECTED OR CATHODIC END

The above table gives the galvanic series. NOTE: Any combinations of these metals will result in corrosion. The severity of the corrosion and the current generated is determined by the greater distance apart the two metals are in this series.

fretting corrosion

Fretting corrosion is defined as surface damage that occurs primarily in oscillatory mating parts due to slip between the parts or the rubbing of the two parts together while vibrating very slightly. Fretting is primarily a physical problem of wear and secondarily a problem of corrosion.

Fretting corrosion gives rise to fatigue type failures because the weakening of the surfaces makes them more susceptible to the origin and growth of fatigue cracks.

Fretting corrosion is primarily found in three distinct classes of parts.

Class I - Parts not intended to move in relation to each other, such as press fits, shrink fits, etc. in non-oscillating parts.

Class II - All parts designed to move in relation to other parts, such as U joints or other oscillating parts.

Class III - Splines where angular misalignment causes relative motion between the spline and its mating component.

Fretting corrosion can usually be identified by reddish-colored oxide on the wearing surface and the abraded (rough) texture of the surface. (See photo on next page.)

FRETTING CORROSION

However, it should be noted that fretting can occur with no visible oxide being formed. For example, tests have been made on close-fitting oscillatory parts immersed in oil. These tests proved that fretting corrosion can occur even when there is no contact with the air. In this case, the abrasion and corrosion are clearly evident, but no rust-colored oxide was formed. The major difference between fretting corrosion and normal wear is that normal wear usually can be controlled through use of a proper lubricant, but this does not necessarily apply to fretting corrosion. The lubrication will prohibit oxygen from reaching the surface and thus cure the corrosion aspect, but the fretting can still occur with much surface damage.

Illustrated are some factors and the effect they have on the rate of fretting corrosion:

1. Speed or frequency - higher speeds give greater frequencies especially in oscillatory parts, which increases fretting.

2. Amplitude of frequency - on oscillating parts, larger amplitudes decrease fretting due to oil being drawn between the parts. On flat parts, higher amplitude increases fretting.

3. Load - on oscillating parts, an increase in load increases fretting. On flat parts, increased load stops the relative motion between parts and decreases fretting.

4. Fluctuating load (even without motion between parts) can sometimes cause fretting.

The most logical and effective methods of preventing fretting corrosion are the following:

1. Increase the load as much as possible on flat close fitting components.

2. Decrease the load as much as possible on oscillatory, close fitting components.

STRESS CORROSION

3. Either eliminate or greatly increase the movement of rolling elements.

4. Use a lubricant (either oil or grease) which is high in rust preventative and oxidation - resistant additives which will constantly flow around and protect the contact surfaces of the rolling elements even during very slight movement.

high temperature corrosion

The fourth type of corrosion is called high temperature corrosion. Elevated temperatures can speed chemical reactions, and hasten the effects of corrosion of metal, usually as scale or surface oxidation.

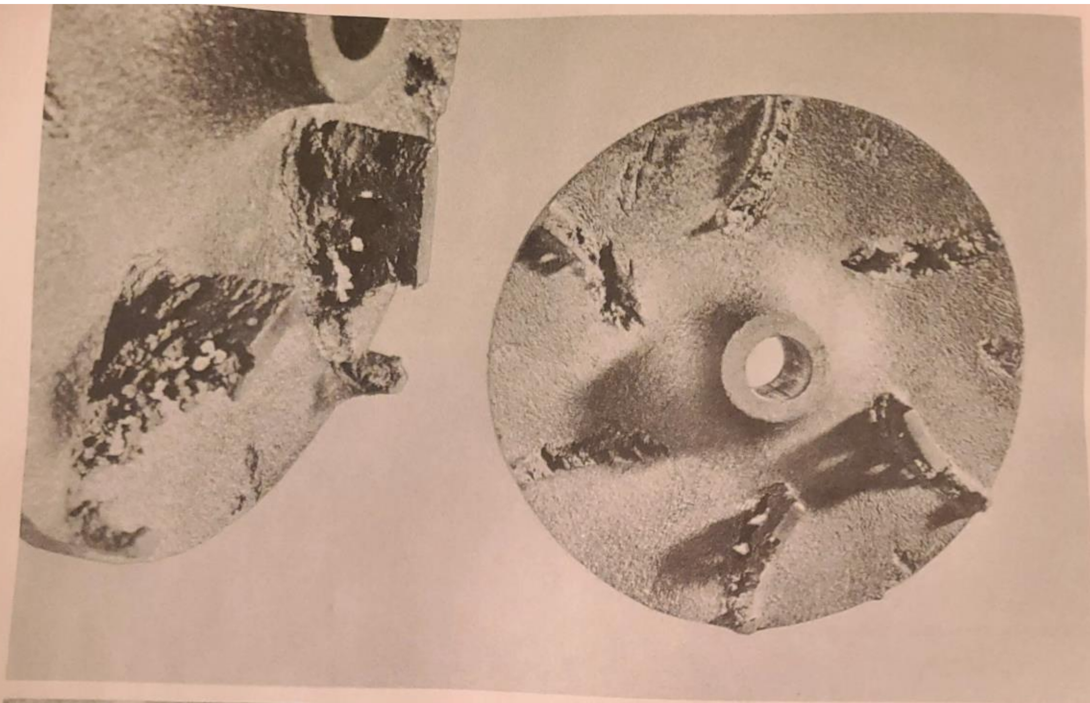
Consequently this type corrosion is extremely critical in engine exhaust components. Very little is known about high temperature corrosion phenomena, but much research is being done in this area.

Prevention of high temperature corrosion can only be accomplished through selection of corrosion-resistant metals and lubricants for high temperature operations.

stress corrosion

The fifth type, stress corrosion, resembles fretting corrosion in the way the stress cracks start and then grow very rapidly. Most metals can be made to fail more rapidly in a corrosive environment, because the corrosion will either embrittle the surface (harden the surface much like glass) causing surface cracking or simply weaken the surface sufficiently for a complete fracture to occur.

These bearings in the above photo failed from a combination of corrosion and localized high pressures near center from unworn ridge on the crankshaft journals.



cavitation erosion

The final type, cavitation erosion, is defined as a form of pitting which is accelerated by erosion until a surface fatigue failure occurs. Cavitation occurs only on surfaces which are immersed in liquid or normally come in contact with liquid. Repeated loading is applied to the surface by the vibrating motion between the surface and the liquid. An example would be a water pump impeller or automatic transmission parts operating in fluid (see photo at upper left). The vibrating motion causes stresses to be set up on the surface of the component. Bubbles form in the liquid during the low pressure cycle and collapse in the high pressure cycle. As the bubbles collapse, they produce high stress impacts which gradually remove particles of the surface, eventually forming deep pits or pock marks.

Another example of the effects of cavitation corrosion is seen on this engine front cover assembly.

NOTE: Notice the deeply pitted surface, much like the erosion of the earth. Components affected are no longer serviceable.

summary outline

Conclusions derived from the analysis and explanation of corrosion types and failures are as follows:

A. Corrosion is the deterioration of a substance (usually a metal) or its properties because of reaction with the environment.

B. Corrosion failures can be divided into six distinct classifications - uniform corrosion, galvanic corrosion, fretting corrosion, high temperature corrosion, stress corrosion, and cavitation erosion.

1. Uniform corrosion, the most common type, is due to chemical action (oxidation usually) between a metal and the environment. Prevention can be accomplished through the proper choice of metal, inhibitors, protective coatings or combinations of the three.

2. Galvanic corrosion is caused by the formation of an electrolytic cell resulting from the potential difference between two metals, one becoming the anode and the other, the cathode. Prevention can be accomplished by insulating dissimilar metals, designing so that a small cathodic area is joined to a large anodic area thus dissipating current at the anode, or using an expendable metal at strategic locations which will corrode and leave the component itself free from corrosion.

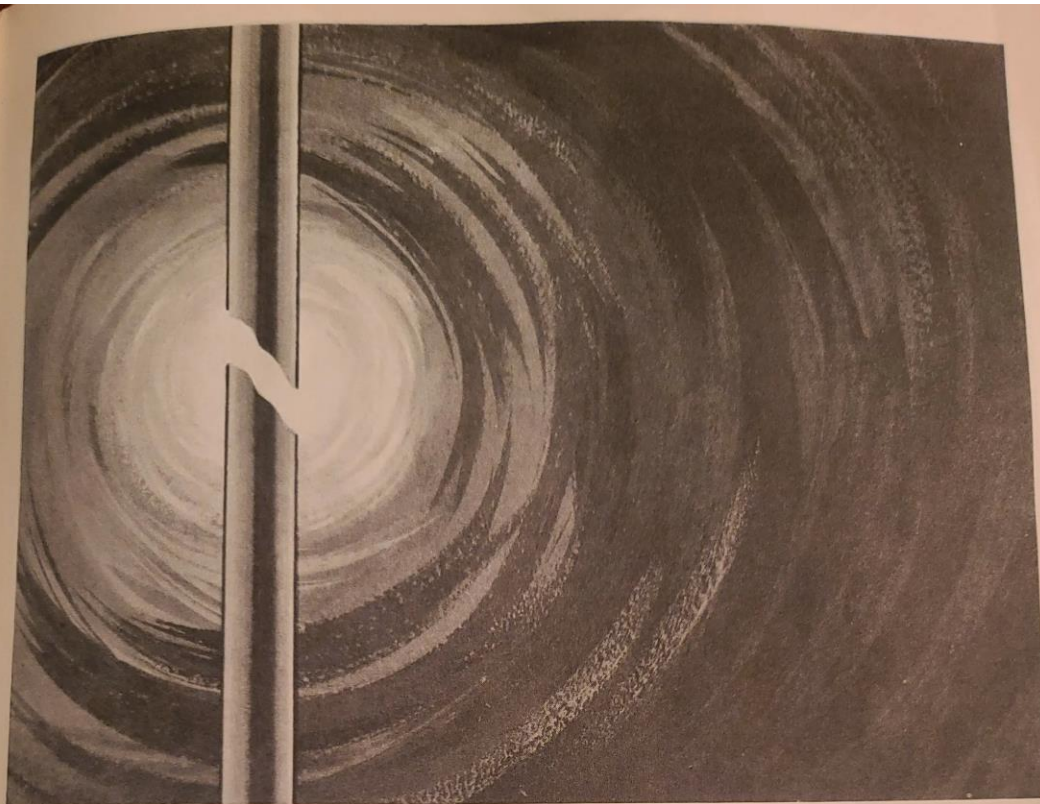
3. Fretting corrosion is caused by surface damage due to vibration in close-fitting oscillatory or flat components, which results in metal particles being torn from the surface of one or both of the components. These particles in turn, react with the atmosphere, corrode, and compound the surface damage by their abrasive nature. Prevention is accomplished by increasing loading in flat components, decreasing loading in oscillatory components, either eliminating or greatly increasing movement of mating elements, and using rust-preventative lubricants.

4. High temperature corrosion is due to very fast oxidation and changes in the surface of the metal during exposure to a corrosive environment. Prevention is only accomplished through selection of corrosion resistant materials and lubricants for high temperature operation.

5. Stress corrosion, or corrosion fatigue, is due to the acceleration of cracks, or fractures in components with high tensile stresses on surfaces in a corrosive environment. Prevention is accomplished by GMC through the reduction of high stresses in manufacturing components and the selection of material having a resistance to stress corrosion.

6. Cavitation erosion is pitting caused by impact of the collapse of bubbles in the high pressure cycle of vibrating or rotating components immersed in liquid. Erosion accelerates the pitting until a fatigue failure occurs. Prevention is accomplished by GMC through design changes to reduce fluid velocity and vibration characteristics.

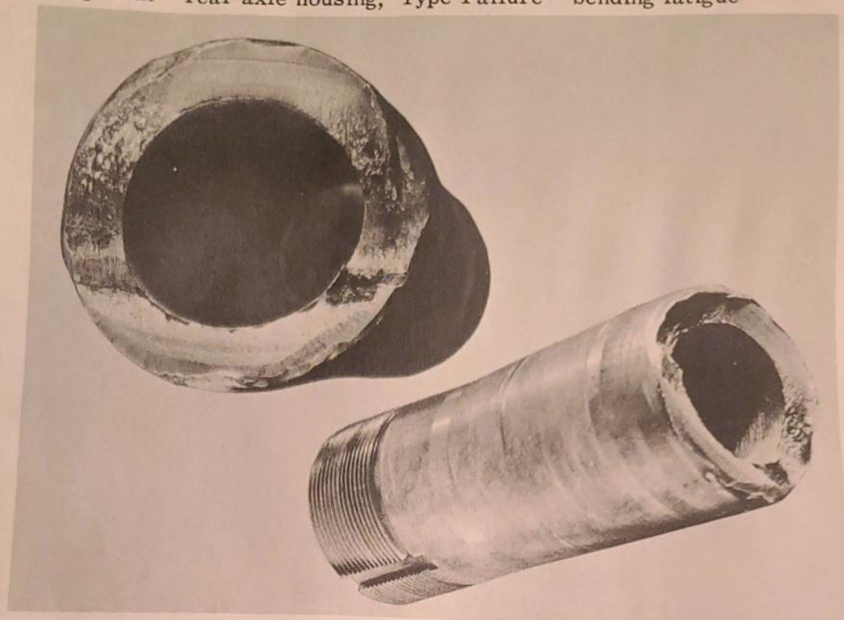
Corrosion failures often complicate the analysis of service failures. In many cases, a thorough knowledge of the types and characteristics of corrosion is essential to the proper recognition of the main cause of failure. Corrosion normally accelerates and contributes to other types of failure.



5 failure identification

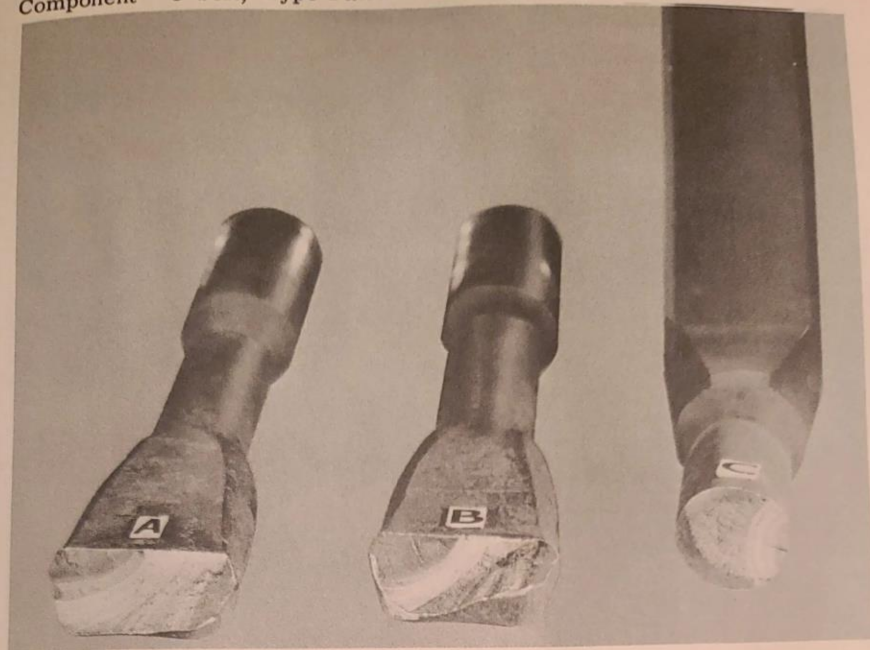
Thus far we have discussed the several different failure types most commonly encountered in truck service. We have also examined the characteristics which classify one type of failure from another. With this in mind, a series of photos of failed parts is presented in the following section as further exercise in correctly identifying a failed part. Each failure is identified by name. In case you may have any questions on a particular failure, refer back to the section of the booklet which explains in detail that certain failure type.

Component - rear axle housing, Type Failure - bending fatigue



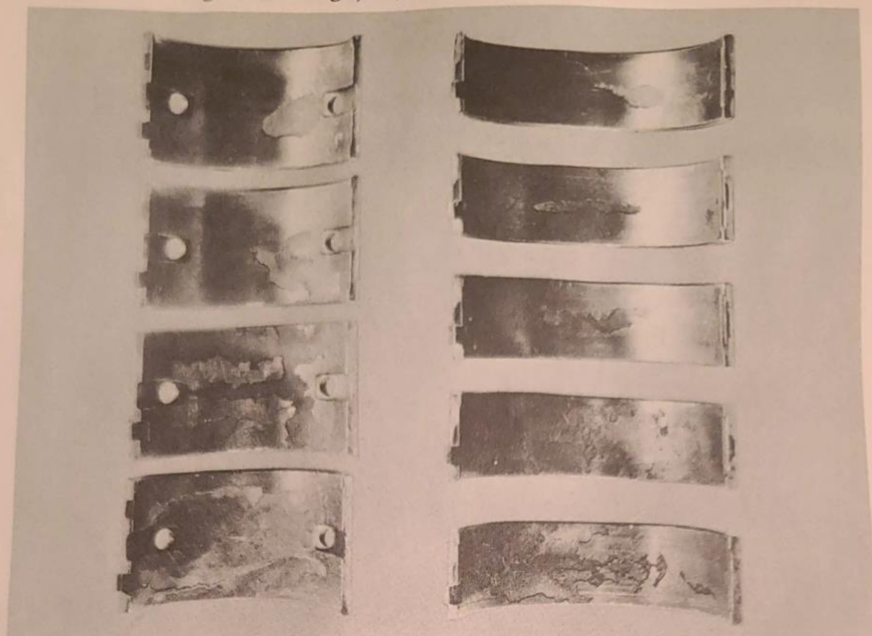
Component - crankshaft, Type Failure - torsional fatigue

Component - U-bolt, Type Failure - bending fatigue

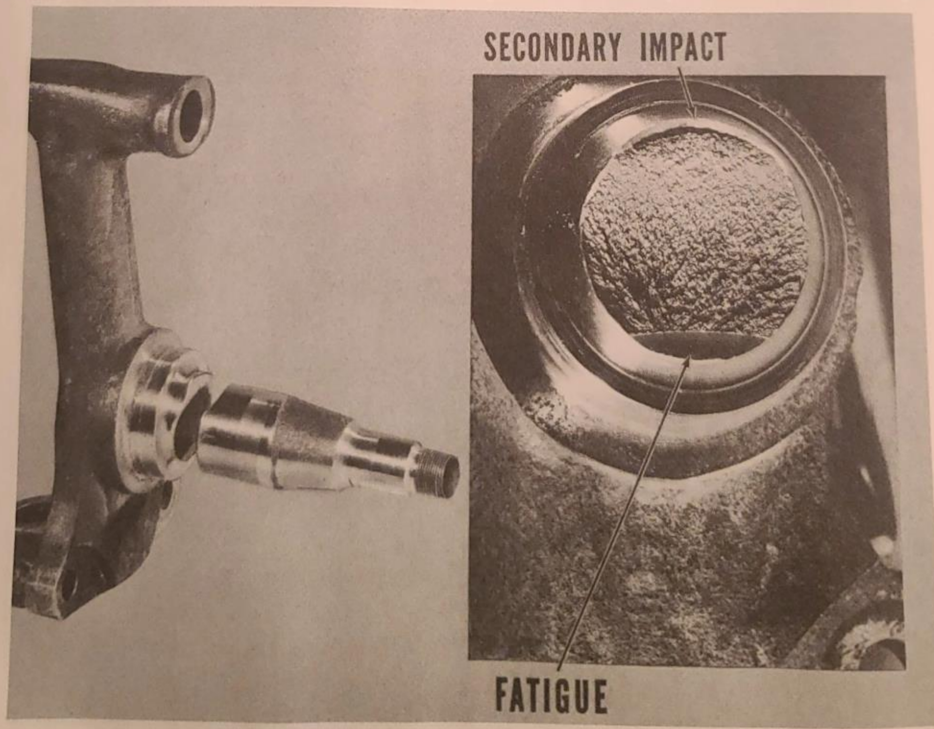


Component-transmission mainshaft, Type Failure-torsional fatigue

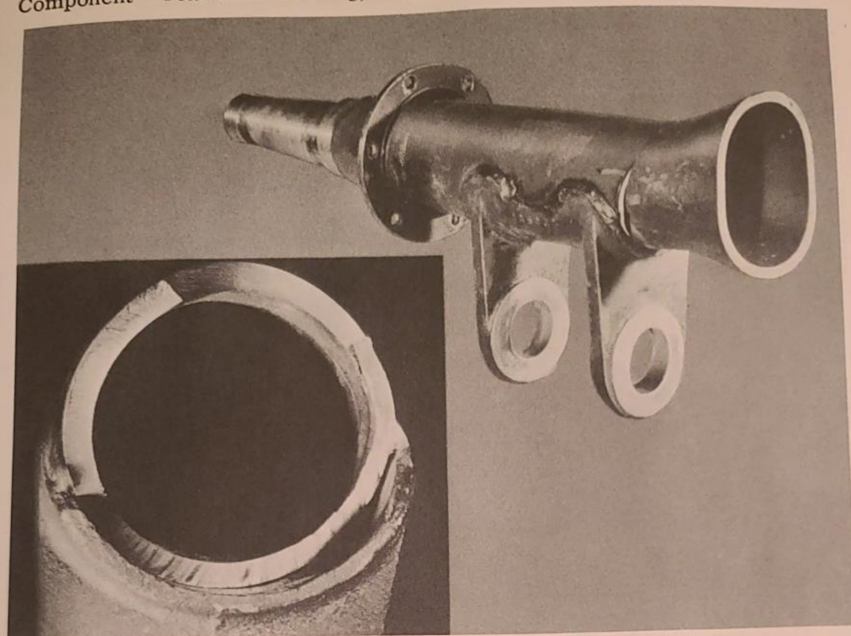
Component - engine bearings, Type Failure - surface corrosion



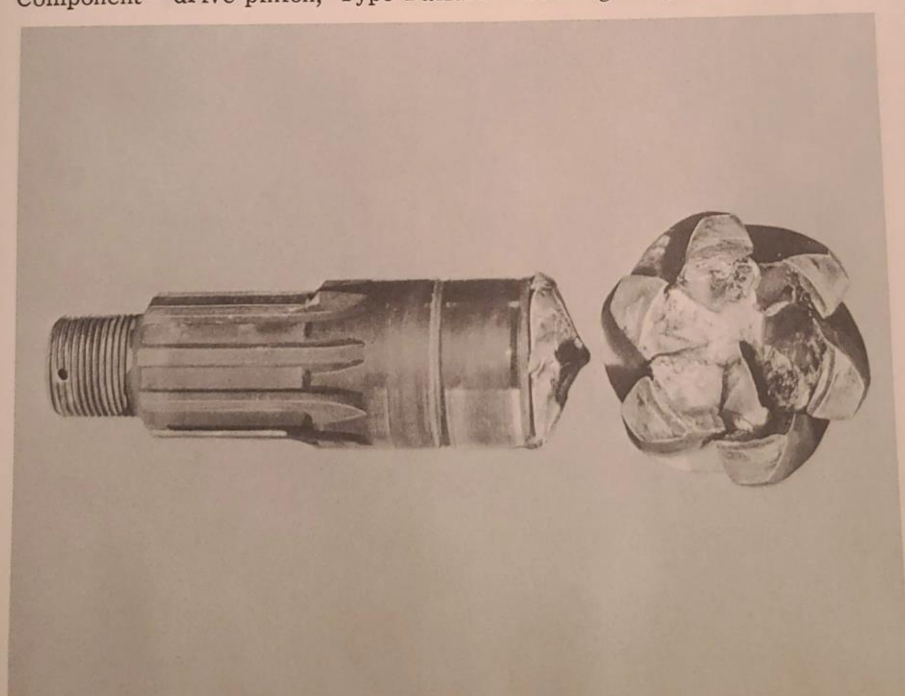
Component-steering knuckle assembly, Type Failure-impact initiated by fatigue



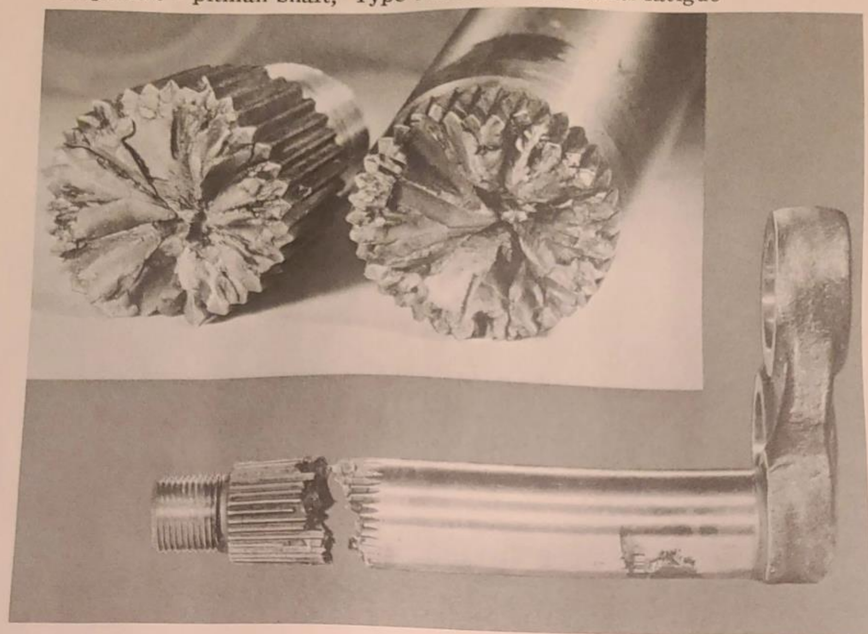
Component - rear axle housing,. Type Failure - bending fatigue



Component - drive pinion, Type Failure - bending fatigue

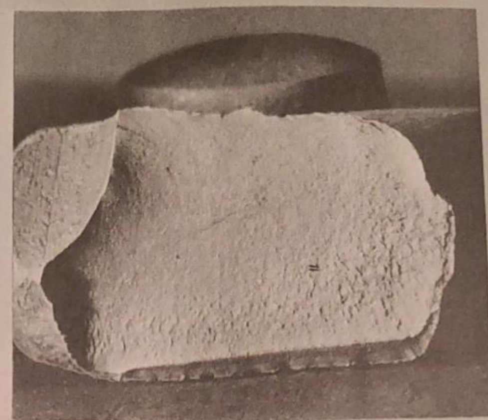


Component - pitman shaft, Type Failure - torsional fatigue

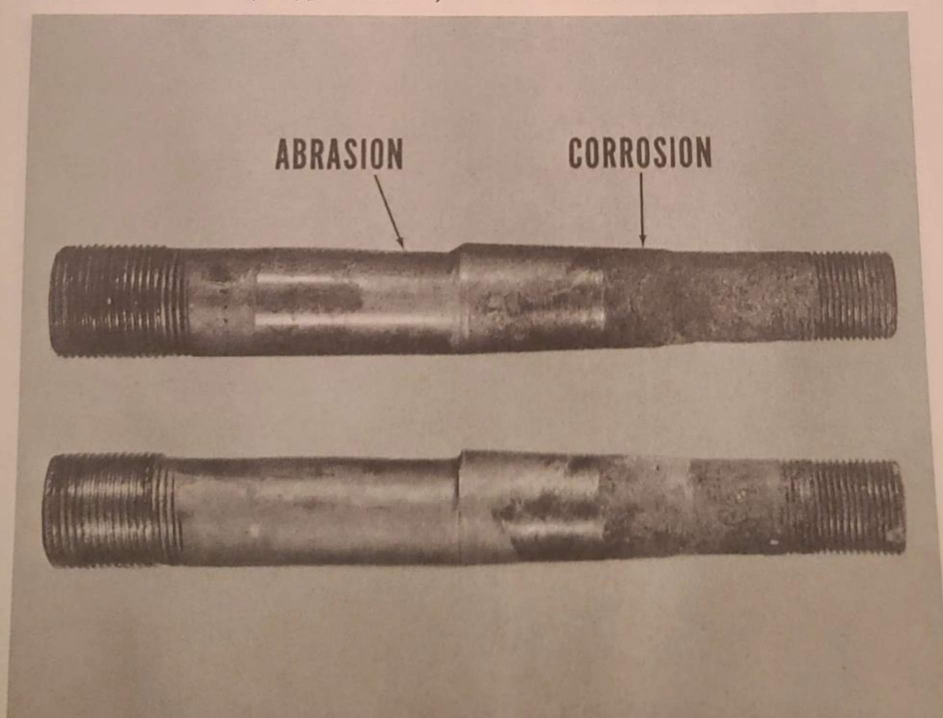


Component - connecting rod, Type Failure - bending fatigue

Component - rear band, Type Failure - bending fatigue

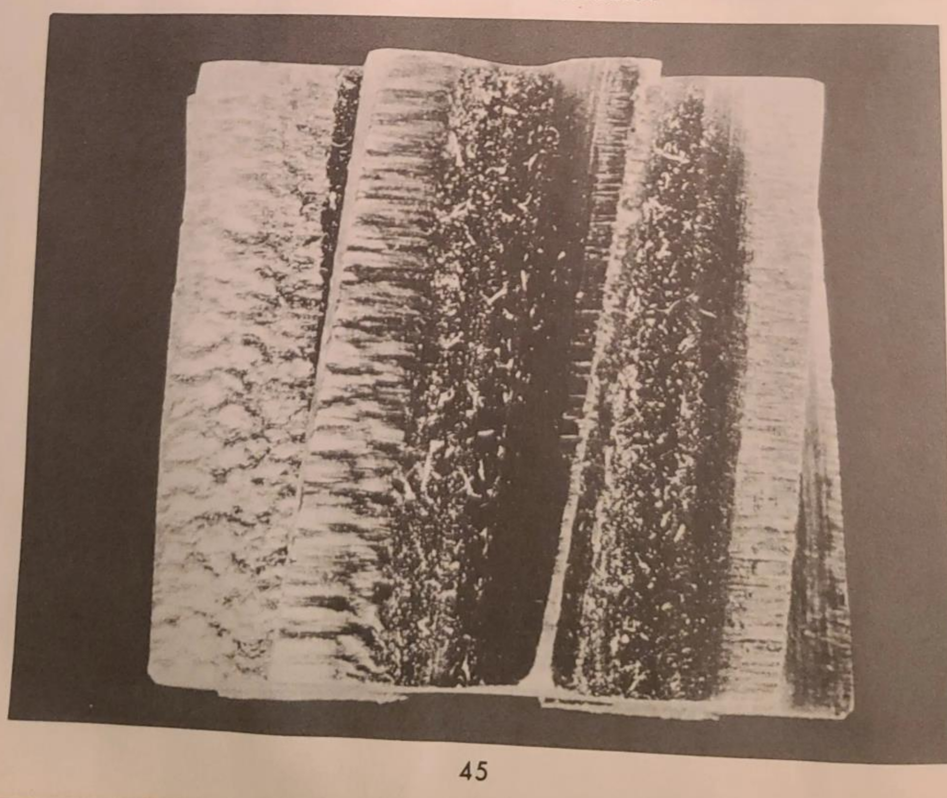


Component - studs, Type Failure, abrasive wear

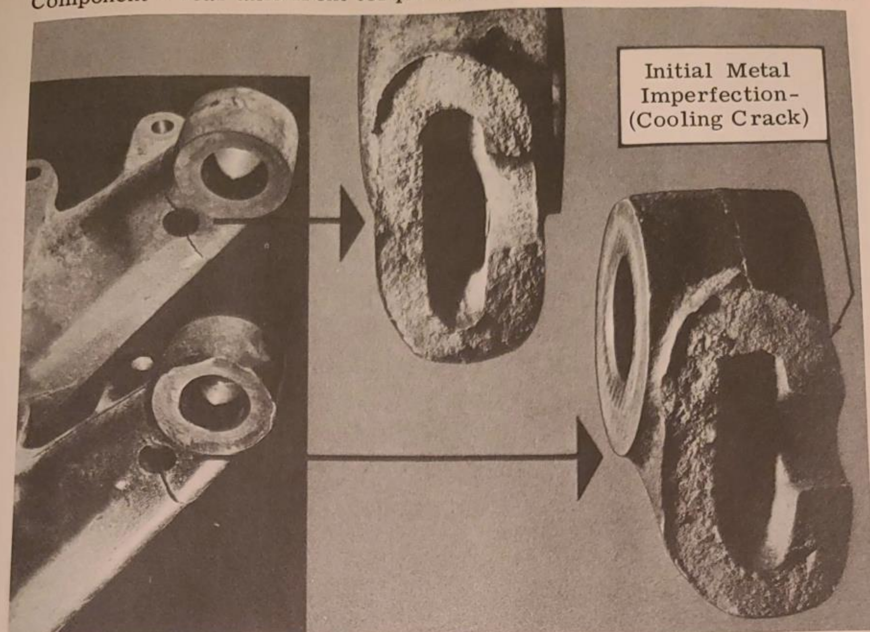


Component - crankshaft bearing surfaces, Type Failure - abrasion

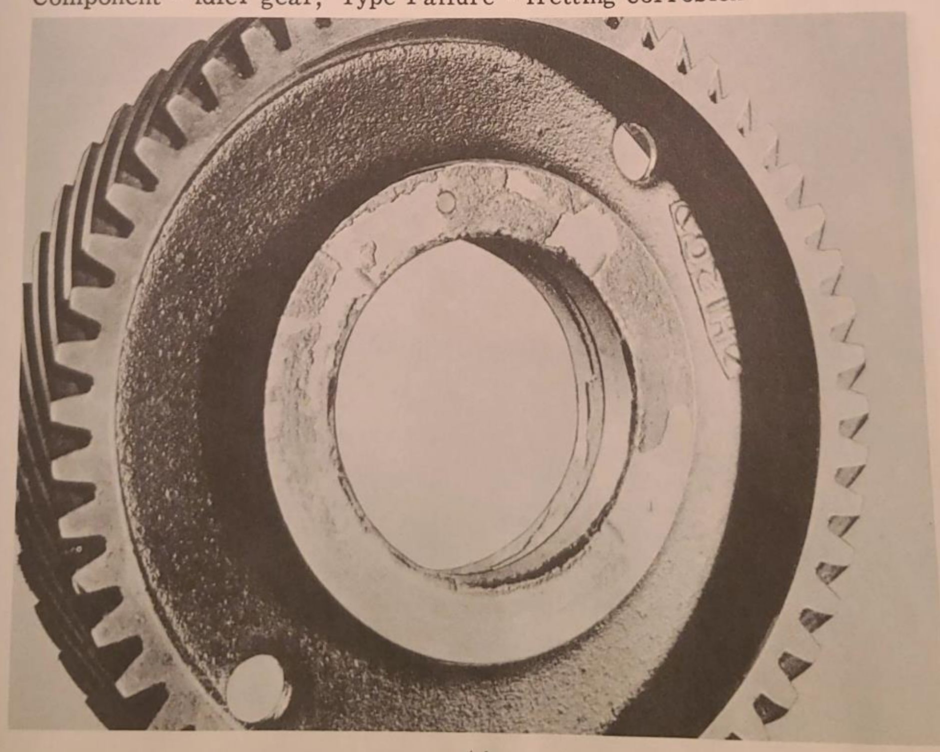
Component - bevel gear, Type Failure - abrasion



Component - rear axle front torque rod brackets, Type Failure - impact

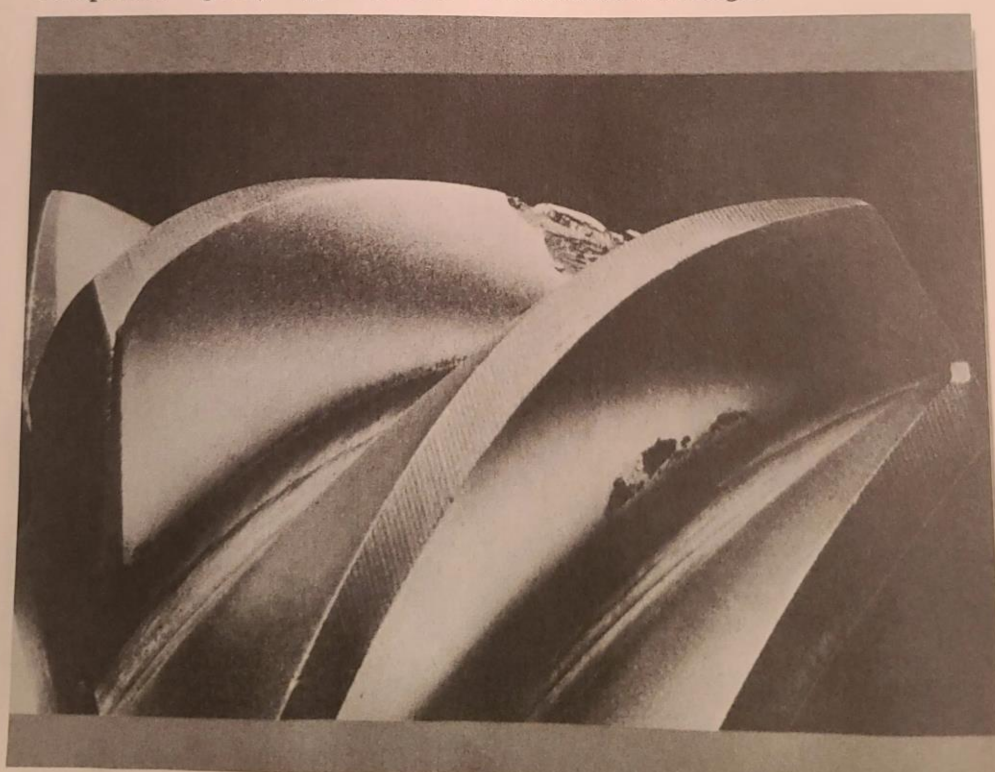


Component - idler gear, Type Failure - fretting corrosion



Component - pistons, Type Failure - high temperature abrasion (scuffing)

Component - gear, Type Failure - contact stress fatigue



conclusion

This concludes our examination of four basic types of failures you may encounter in truck service. It has been our goal to acquaint you with the possible causes for each of these failures. Failures such as fatigue and shock are most often caused by driver or vehicle abuse. Corrosion and abrasion failures may be the result of poor maintenance practices. Because of the high quality and standards built into today's new trucks, proper operation and maintenance probably would have avoided each of the failures you have seen illustrated here.

To replace broken parts without inspecting them and determining what caused them to break can lead to repeat failures, down time and expense, with the resultant owner dissatisfaction.