TROUBLESHOOTING

Down Hole Hammers perform a very rugged task – they drill holes in solid rock. After just one use they can look a very rough and ordinary piece of equipment. To the contrary, they are a highly engineered drilling tool and extreme demands are placed on the various components which make up the drilling unit.

From an Engineering – Metallurgical perspective all these demands, including performance and reliability, must be addressed within the confines of the hammer envelope. Unlike other engineered equipment or components, dimensions cannot be significantly increased in size to reduce the risk of breakage due to the ever increasing stresses applied by the use of high energy compressed air.

The demands don't stop at that. The hammer is expected to survive the gruelling rigours of drilling which often border on the unthinkable, such as:

Interruption of the atomised oil lubrication feed

Water or foam is injected which destroys the lubricating properties of oil, and as well provides a good electrolyte for corrosion attack

The ingress of dirt or foreign bodies

The use of ever increasing operating air pressure

To produce a reliable and sound performing hammer and bit involves four critical elements:

Superior design

Quality steel grade selection

Expert heat treatment

Quality manufacture

To settle for a lesser standard for any one or more of the four elements would compromise the product. SH&B uses industry leading design, steel grades, heat treatment and quality manufacture for all our products. This has helped us achieve a successful global market in reverse circulation tools and consumables.

Like all manufacturers of quality product we do from time to time experience some failures related to manufacture. However, when these are identified our company is committed to rectifying the problem immediately.

At times the causes are beyond the control of a driller given the 'nature of the conditions' we are dealing with, However, SH&B has a strong belief that understanding the mechanism behind the cause of a failure and addressing it will minimise the chances of it happening in the future.

Percussion Drill Bit

The Percussion Drill Bit is what carries the piston energy to the rock face, therefore the condition of the bit cutting face should be well maintained. As the bit accumulates drill time the buttons and the steel will start to show a wear pattern. The pattern and rate of wear will depend greatly on the geological formation being drilled.

In soft formations the buttons on the drill bit may form a “snakeskin” effect on the surface, these surface cracks must be ground off to prevent bit failure. In hard formations where the bit wears quickly “flats” will be formed on the buttons. These flats should be ground away before they reach half the diameter of the button. Some formations wear away the steel of the percussion bit leaving the button exposed. The button must be ground down to prevent button failure. The following table indicates the recommended height of button bit exposed above the steel of the percussion bit.

Button Diameter	Height of exposure		
mm	Inches	mm	Inches
11	7/16	6	1/4
12.5	1/2	7	9/32
14.5	9/16	8	5/16
15.8	5/8	9	3/8
19	3/7	13	1/2

Bit Shanking

Shanking of a bit, be it through the splines or the upper and lower bearing guide diameters in almost all cases results from ‘heat checking/galling’.
Spline fracture
Crack initiation on the ‘thrust’ face of the splines can develop from two differing aspects of drilling operation. They are:
Insufficient weight on bit
Excessive weight on bit
Insufficient weight on bit and working of unconsolidated ground causes excessive spline movement between the bit and drive sub. The extended sliding movement, under normal torque loading, in itself generates additional heat energy. Temperatures in excess of 720°C can develop from this action on the spline surface thus causing a very shallow ‘rehardened’ zone to form over most of the contact length.
The contact area generally appears as a bright smooth surface. However, when viewed through a magnifying lens small very fine transverse cracks can be seen. Under the vibrating conditions of the drilling operation one or more of these cracks may grow as a fatigue fracture, ultimately causing catastrophic failure – shanking – see Figure 5.

Spline fracture

Excessive weight on bit, running large wear flats on buttons; and the usage of too large a diameter head to bit shank diameter are all factors which develop very high rotational torque levels. These conditions cause massive galling on the spline thrust face, as shown in Figure 6, with associated heat check cracking. As in the subsequent growth of a fatigue crack will cause shanking.

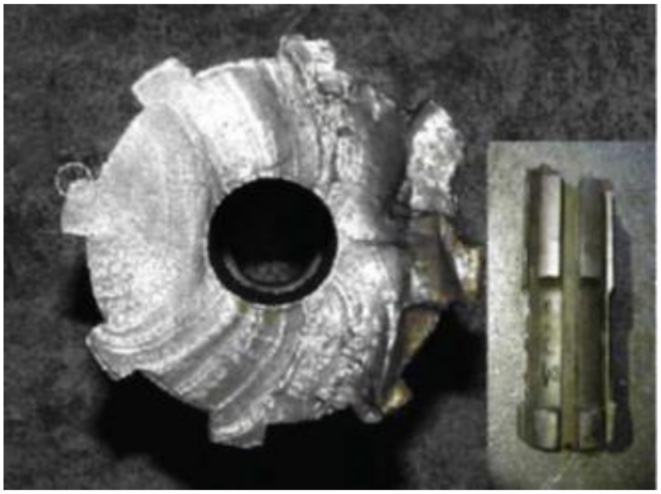
FIGURE 5 - Bit spline fracture


FIGURE 6 - Bit failure due to spline galling

Broken inserts

Button percussion bits can continue to drill effectively even with a certain number of missing inserts. However, in order to minimise possible additional damage to buttons, broken or chipped insert buttons should be ground.
Chipped buttons will continue to function. Sharp edges should be ground smooth to minimise the chance of further damage.
Broken buttons should be ground flush with the bit head to prevent any further breakage which could damage other buttons which are still intact.

Heat cracks on buttons

While inspecting a bit for reshaping, check for rough areas on the buttons that appear like snake skin. These are fine cracks caused by overheating and if not ground off can lead to premature button failure.
In order to minimise the chance of further damage, grind the button to remove the cracks, reshaping as necessary. If detected on a normal sharpening schedule this will require removal of only a small amount of the carbide button.

Chipping on gauge carbides

Fatigue cracking may occur on gauge carbides, particularly in very hard ground. This manifests itself as small chips coming away from the outer gauge. These areas need re-grinding as soon as possible to avoid complete failure of the button.

Note: If this problem persists a change to an alternative grade of carbide may be advantageous.

Carbide failures

Tungsten carbide buttons used in the hard rock drilling industry, in most applications, are made up of 94% tungsten carbide and 6% cobalt.
The tungsten carbide is in the form of very small and varied size grains while the cobalt is the matrix which during manufacture has melted, flowed and enveloped the tungsten grains, see Figure 16.

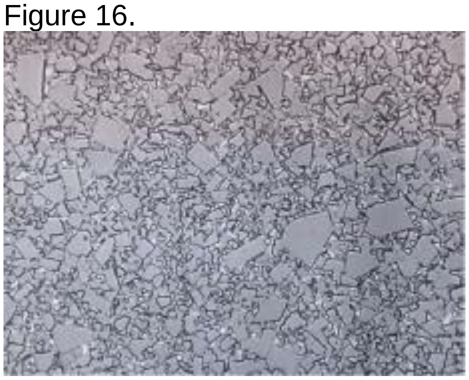

FIGURE 16 - Micrograph of tungsten carbide button

The tungsten carbide is extremely hard, brittle and wear resistant whereas the cobalt is relatively soft and tough. The general rule of thumb is, the harder the button the less tough it is and therefore more prone to breakage. The softer the button the more tough it is but more susceptible to wear. Increasing tungsten carbide grain size will also effectively increase the button’s toughness properties

Tungsten carbide, when stressed (loaded) in direct compression is one of the strongest materials on earth. However, when loaded in shear, that is, with some component of lateral loading, it is relatively weak.

Excessive wear on buttons can be attributed to either one or a combination of factors, such as:

- Composition of rock – e.g. quartz content
- Excessive weight on the bit
- Poor clearing of bit face (secondary grinding)
- Excessive hammer rotational speed
- Unsuitable grade of carbide (either too soft and too hard)

Fracture of buttons occurs, in the main, by the four following causes:

- Stress overload
- Snake skin cracking
- Thermal cracking
- Shear fracture

Stress overload

The tell-tale evidence that a button has failed by stress overloading is the resultant 'cusp' fracture. That is, on the fracture surface a small peak forms diametrically across the button and always in a plane, approximately at right angles to the direction of bit rotation. See Figure 17.

FIGURE 17 - Example of button with "Cusp" failure

The sequence of a 'stress overload' failure is that generally the trailing section of the button domes will break away first followed by fracture of the leading section, as shown in Figure 18. The characteristics of the load (stress) planes that occur during the failure process are such that an upward cusp fracture pattern results.

Stress Overload type failures can be prevented by:

- Reduction and control of weight on bit,
- Increase of rotation speed slightly, particularly if there is evidence of wear on the leading side of the button
- Frequent resharpening to restore the original button profile

Snake skin cracking

Snake Skin Cracking is most common on gauge row buttons but can also occur on outer face buttons.

Its development is due to the contact area of the button becoming fatigued from the dual action of cyclic impact stress application and thermal stressing. A network of fine very shallow cracks appear which resemble a snake's skin and for most times, require a magnifying lens to clearly detect, see Figure 19.

If snake skin cracking is allowed to remain, continued working of the bit can cause the cracks to grow deeper and eventually cause catastrophic failure. The resultant fracture displays a multifaceted surface. Failure can be prevented /minimised by more frequent grinding of the buttons to remove the cracked skin.

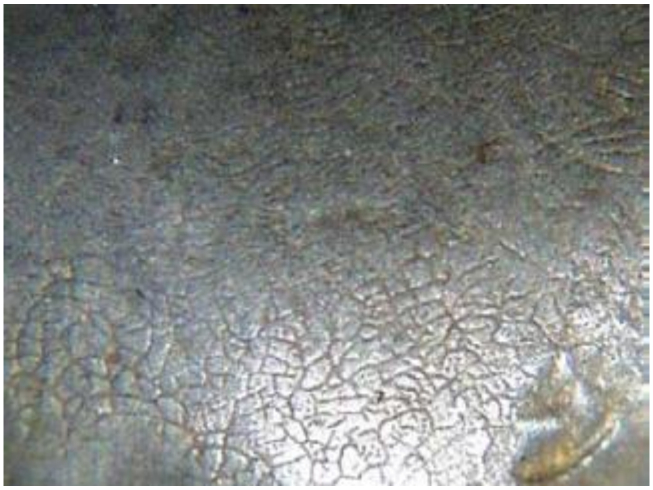

FIGURE 19 - Snake skin on tungsten carbide button surface

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Thermal shock cracking

Thermal shock cracking develops from the generation of excessive and sustained frictional heating as the carbide button slide against the rock surface in the hole. High hardness, fine grained rock appears to influence this type of cracking.

Cracking generally takes the form of sweeping arcs across the wear/contact zone and often with associated surface chipping, see Figure 20. Like snake skin cracking, crack growth can lead to multifaceted catastrophic failure. Thermal cracking can be prevented /minimised by slower rotation speed, lower weight on bit and the use of a tougher (softer) grade of carbide.

FIGURE 20 - Thermal cracking on tungsten carbide button surface

Shear fracture

This type of failure is common on gauge row buttons. The ever changing button profile due to wear from the ‘wall’ of the hole causes the direction of applied load to change from direct compression on a new button profile to shear load. As mentioned above, tungsten carbide is very strong when subjected to compressive loading but relatively weak when a shear load is applied.

Regular resharpening to restore original button profile is the only remedy.

Lost buttons

Tungsten carbide buttons are held in the bit body by way of an interference fit. That is, the holes in the bit body are drilled at a slightly smaller diameter than the diameter of the button..

Any operational condition such as:

- Body wash
- Excessive hammering when lifting the bit off bottom

- The generation of frictional heat can effectively reduce the body ‘grip’ on a button and thus cause it to ‘pop out’, as explained below:

Body wash effectively reduces the ‘grip length’ on a button but in particular when it occurs to the bit head diameter the side of the gauge button is abraded away making it easy for the button to loosen and fall out;

Drilling in very soft ground where constant flushing is necessary or continual lifting off bottom with the hammer running, can cause buttons to loosen and be driven out of their hole; the steel from which the bit body is made has approximately twice the thermal expansion rate of tungsten carbide. Heat generated at the bit head from either difficult drilling or trying to free a ‘bogged’ hammer causes the interference ‘grip’ to lessen. Striking of the bit by the piston can thereby force a button out of its hole.

Hammer

There are basically two different types of fracture that are encountered with hammer and bit failures. They are fatigue fracture and brittle fracture.

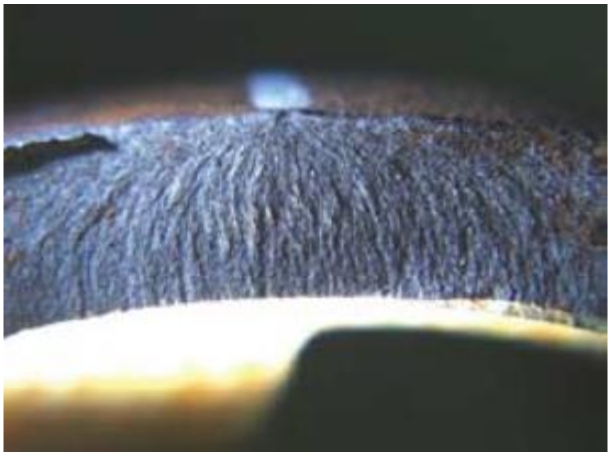
Fatigue fracture

Fatigue fracture develops from repeated or cyclic application of load (stress).
This mode of fracture accounts for at least 95% of drilling equipment failure. Obviously, with a vibrating/impact tool this is easily understood.
Fatigue cracks are progressive, beginning as minute cracks that grow under the action of fluctuating stress application.
A fatigue fracture is readily identified by its conchoidal growth rings, often called ‘beach markings which radiate out from the crack origin. The beach markings develop from the arrest and propagation of the crack. Its rate of growth can vary considerably depending on the loading being applied.

Brittle fracture

Brittle fracture results from a stress overload, facilitated by a stress concentrator such as a sharp corner or a change in diameter/cross section.
Its fracture is identified by a bright granular/crystalline appearance and often will display ‘arrow heads’ called chevrons which always point back to the point of origin.

Brittle fracture is instantaneous in its action as it propagates at many thousands of feet per second.



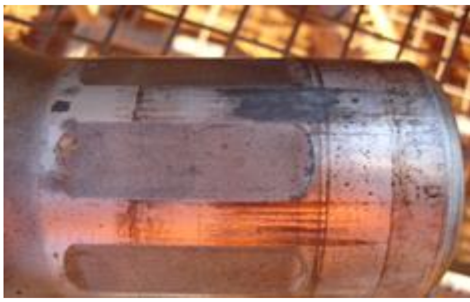
Heat

Probably the single most common cause of hammer and bit failure is the localised generation of heat. That is, heat which in most cases results from friction due to metal to metal sliding contact. Frictional heat can generate surface temperatures in excess of 720°C. When this happens localised rehardening of the steel surface occurs. The ‘as formed’ rehardened steel microstructure is very hard and brittle and therefore extremely prone to crack development. Often operational conditions will cause very high forces to be applied to the two opposing sliding surfaces. (e.g. high torque loading on bit). When this situation develops the asperities on their surfaces can with the aid of associated high frictional heat, instantaneously weld together. Continued movement of the sliding surfaces then causes the micro welds to tear apart thus producing a galled (torn) surface. Considerable heat can be generated when this process occurs often producing a visible blue heat tint (oxidation) in areas adjacent to the galling. In extreme cases of galling the rehardened subsurface zone has been found to measure 2.5mm (1/8”) in depth.
The fine cracks which develop in the rehardened zone, called ‘heat check cracks’ are generally shallow, somewhere between 0,1mm and 1mm (0.005” and 0.040”) deep. However, as a general rule, the deeper the rehardened zone the deeper the heat check crack will be.
The following are examples of component failures where the origin of fracture has been due to the formation of a heat check crack caused by frictional heat/galling.

Piston failure

The most common failure zone of a piston is through its bearing areas. The photograph clearly shows surface galling and associated heat tinting at the point of fracture origin.
The fundamental cause of this type of failure is due to ‘loss of lubrication’. What we mean by loss of lubrication is the loss or break down of the oil ‘wedge’, which keeps the piston separated from the cylinder or sleeve bore. Obviously, when this occurs metal to metal contact results and thus the generation of frictional heat and possibly galling.
The common causes for the “loss of lubrication” are as follows:

Insufficient Volume of Oil being Supplied to the Hammer
Use of Water or Foam Injection
Ingress of Dirt in Hammer
Cylinder Bore Damage
Incorrect Oil Viscosity




Insufficient Lubrication Supplied to the Hammer

Use of Water or Foam Injection
Water and foam emulsifies mineral oil and therefore destroys its lubricating properties. As per established drilling practice, additional oil must be used during these periods, sometimes up to double the normal usage.
Ingress of Dirt in Hammer
The lodging of dirt between the piston and cylinder bore will laterally displace the piston. In doing so the protective 'oil wedge' is broken down allowing metal to metal contact to occur.
Cylinder Bore Damage
Failure of a piston invariably causes physical damage, namely 'lumps and bumps', to the cylinder bore surface. The damage effectively reduces the bore diameter which in turn can rapidly cause failure of a newly installed piston – due to metal to metal contact.
We strongly recommend honing of the cylinder bore prior to fitting a replacement piston.
Incorrect Oil Viscosity
If too low viscosity oil is initially selected for a hammer which is to operate in a high ambient temperature environment, the 'thinning' effect may reduce its properties to the extent that it may not have the film strength to separate the two metal surfaces.

Bearing guide fracture

It is more common for the lower bearing guide to fracture than the upper bearing guide. Again, it is the same friction/galling mechanisms which cause failure.
Insufficient weight on bit or deflection of bit will cause the bearing guides to impinge and gall on the mating surface of the drive sub. As well, the operation of bits with head mass above that

recommended for the specific shank size will increase the leverage on the bearing guides, thereby causing galling and subsequent failure.

Drive sub failure

Drive subs can fail in two different ways. Again, heat checking (rehardening)/galling of the internal bearing surface, as mentioned above, or to the thrust face of the splines, will manifest as a fatigue fracture and thus cause breakage.
The other type of failure is by brittle fracture. The fracture most times occurs at the root of the shoulder where there is a change of metal cross sectional area.
The fracture surface displays a brittle ‘crystalline’ structure with its characteristic ‘arrow head’ markings directing back to the point of fracture origin. Refer Figure 7.
Brittle fracture propagates as an instantaneous break, and is due to a sudden stress overload, influenced by the ‘notch’ effect of the change of cross section.
This type of failure results from a loose joint which can occur when hammering without rotation, Insufficient weight on bit or when drilling soft and unconsolidated ground.

Cylinder failure

Cylinder failure can result from differing causes, heat checking, incorrect breakout procedures and corrosion. Refer to CORROSION section for the latter example.

Heat checking – thread galling
Cases of heat check cracking have been found on the thread profile (drive sub end) of cylinders. The basic cause has been the practice of poor alignment of the drive sub to cylinder, the use of too high rig rotation speed when tightening drive sub, and probably insufficient quantity of grease lubricant.
Another related example is when drillers use the rig to align and assemble the cylinder onto the drive sub. Instances can occur where the cylinder end face engages and rotates on the strike face of the bit or the top edge of the drive sub, thus creating considerable frictional heat and hence subsequent heat check cracking. Figure 8 is a photographic record of this type of failure.

Note: In all the foregoing examples of component failure the generation of frictional heat has been the underlying fundamental cause of failure.
The mechanisms of failure are that when frictional heat has caused the generation of localised surface temperatures in excess of 720°C (approx) localised hardening occurs. Small fine cracks develop in the rehardened metal. From that point on the crack/s, under the influence of the vibrating/impacting tool, transform to a fatigue fracture which slowly propagates across the metal cross section.

IT MUST BE CLEARLY UNDERSTOOD THAT THE LAPSED TIME PERIOD FROM WHEN THE INITIAL FRICTIONAL HEAT DAMAGE OCCURS TO THE MOMENT OF CATASTROPHIC FAILURE (BREAKAGE) CAN VARY FROM HOURS TO DAYS TO WEEKS AND MAY BE EVEN MONTHS. THE TIME FRAME IS DEPENDENT ON THE USE AND LEVEL OF STRESS THE PARTICULAR COMPONENT IS SUBJECTED TO.

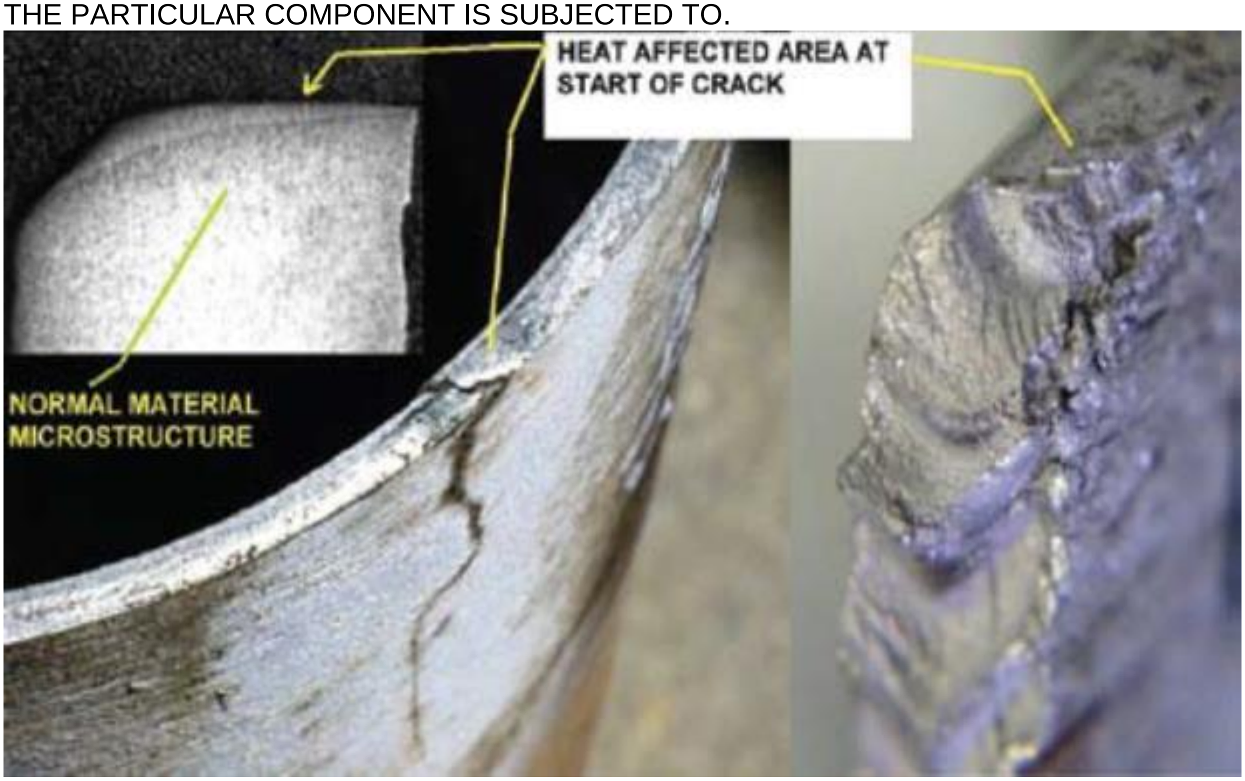


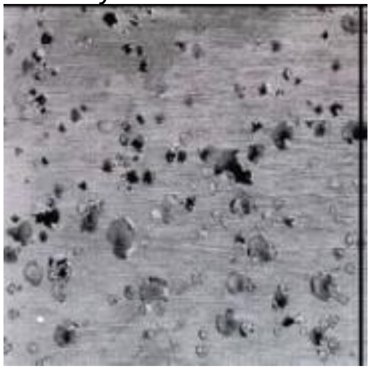
FIGURE 8 - Cylinder failure

Corrosion

THE INCIDENCE OF FAILURES WHICH ORIGINATE FROM CORROSION ATTACK RANK SECOND TO FAILURES CAUSED BY HEAT CHECKING.
General surface corrosion or 'rusting' occurs on all drilling equipment once its protective film has worn away and its surfaces exposed to moisture, either via atmospheric vapour, or by direct wetting. This form of corrosion attack has negligible influence on component failure.
The most damaging form of corrosion and the type which invariably leads to catastrophic failure, is PITTING CORROSION.

The definition of Pitting Corrosion is ‘localised corrosion of a metal surface, confined to a point or small area, which takes the form of cavities’.
In broad terms pitting corrosion begins by the formation of an electrolytic cell. It occurs when a very small area of the metal surface, usually at the site of a slight imperfection, becomes an anode (active area) and the larger surrounding area the cathode (passive area). An electrolytic cell must always have an electrolyte to couple the anode and cathode. An electrolyte can be one of many solutions, e.g. bore water, salty water, acidified water or drilling foam. The more dissolved salts the water contains the more aggressive and rapid will be the pitting attack.
Once pits are initiated, they may continue to grow by a self-sustaining, or auto-catalytic process. That is, the corrosion processes within a pit produce conditions that are both stimulating and necessary for the continuing activity of the pit. Figure 9 is an illustration of (a) severe deep pits, and (b) shallow pits.
It is often the case that the naked eye cannot detect corrosion pits due to their relatively small opening and also the presence of general surface corrosion. Positive identification requires the use of a low power microscope. However, for most times the pits will have eroded a much greater size hole beneath the surface.

The most common areas of pitting corrosion attack on hammers and bits which invariably lead to failure are: cylinder threads and pistons. The first two examples are areas where ‘water’ accumulates and stagnates, thus creating the ideal environment for pitting to occur.
The effect of corrosion pits on a component is that they act as stress raisers. That is, they will concentrate what is a normal and acceptable level of operational stress and magnify it to a higher level which will initiate crack development.
Pitting corrosion has a devastating effect on the fatigue limit of steel. It can effectively reduce its value by 25-40% and in some instances by as much as 60%.



(A) severe deep pits


(B) shallow pits

This phenomenon is common to drilling equipment and its effects are catastrophic. There are known cases where pitting corrosion on a piston nose has resulted in the top section of the piston breaking off after servicing only 20% of average expected life. Similarly with cylinders, circumferential cracking at the drive sub end thread has been known to develop after 1,000 to 2,000 metres of drilling.

Figures 10, 11 and 12 are examples of premature failure of a piston, cylinder and drill bit.

It should be emphasised that corrosion attack on drilling equipment can be controlled and thereby premature failures minimised by regular maintenance of protective barriers and the adherence to correct procedure for ‘Parking’ and/or ‘Storage’ of hammers and bits.

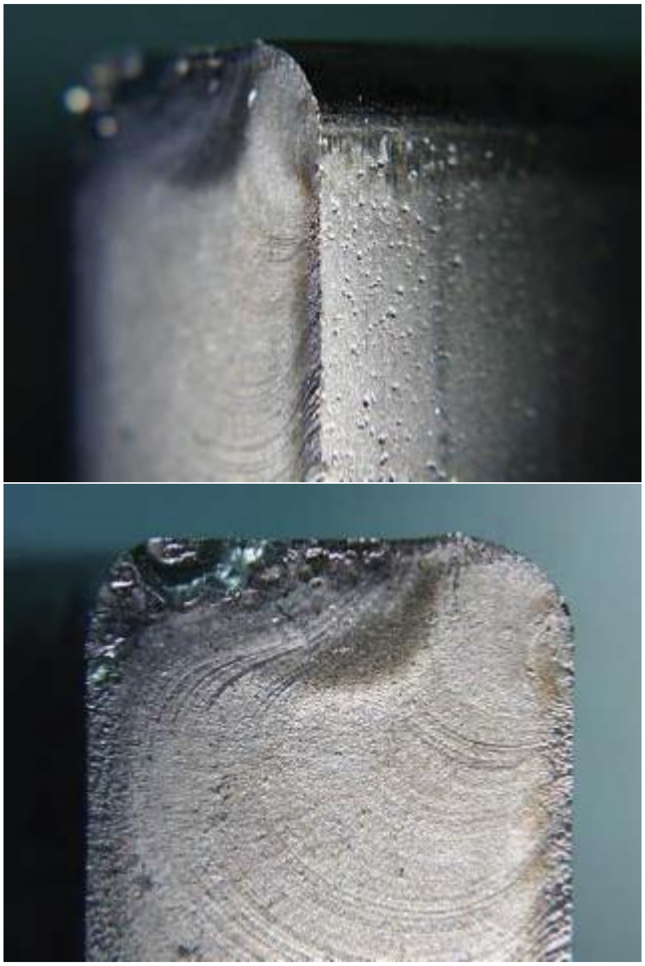


FIGURE 10 - Piston failure by corrosion

Troubleshooting Table

Hammer Trouble Shooting		
Problem	Probable Fault	Corrective Action
Hammer will not start	Low Pressure	Increase Compressor discharge pressure, use Booster Compressor
	Incorrect Hammer Assembly	Check Hammer Assembly
	Dirty Hammer	Clean Hammer
	Damaged Components	Overhaul Hammer

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Intermittent Operation	Worn Components, faulty Valve, Damaged Drill Bit or Drive Sub	Overhaul Hammer
	Dirty Hammer	Clean Hammer
	Too much down pressure	Set the down pressure until the rotation starts to bind, then back off the down pressure until the hammer rotates smoothly
	Rotation speed too slow	Percussion Drill bit rotational speed of between 300mm and 400mm per second. Place chalk mark on drill string and check the advance vs the rotation. If the Drill string advance more than 12mm per rotation increase the rotation until the advance is 10mm per rotation.
DTH Hammer will not stop Hammering	Plugged Bit or Inner Tube	Lift hammer off bottom and blow air down. If still continuous hammer inspect inner tube and Percussion bit for blockages.
	Worn Piston	Measure the Large diameter of the piston, if air leaks past this it can cause the hammer to fire.
	Too much water injection	Reduce water injection
Check Valve not sealing	Broken Check valve spring	Replace check valve spring
	Damaged check valve	Check urethane face and internal seal, replace if worn or damaged
Low penetration/ Low Pressure	>Worn internal components	Inspect piston, piston case and inner tube. Measure diameters and replace if clearance is greater than 1/2mm between bearing surfaces.
	Lack of lubrication	Ensure an oil film is coming from bit splines. (place cardboard under hammer to check)
Thread Damage to Top Cylinder or Drive Sub	Hammer not correctly torque up prior to Drilling	Refer Make up torque table (Page 24)
	Incorrect breakout location.	Incorrect breakout location.
	Piston Galling	Ensure an oil film is coming from bit splines. (place cardboard under hammer to check)
	DTH Hammer badly bogged which can cause piston case to distort causing heat checks and cracks	Flood tool with water when badly bogged
	Using breakout wrench over wrong areas can cause piston case to distort which can initiate heat checks in piston	Use breakout wrench in the approved areas only
Piston strike face cracking	Not enough down force	Increase down pressure until rotation binds and then back off until rotation and pressure become smooth.

	Contamination from excess or acidic water causes pitting in the piston face	Avoid excessive water during Drilling operation. Only use pH neutral water free from contamination.
	Damaged Percussion bit	Ensure strike face of percussion bit is not damaged.
Crack in Piston Case	Excessive external wear	Measure diameter of piston case.
	Heat or weld applied to piston case	Replace—never use heat on piston case
Drive Sub cracked down spline	Incorrect down pressure	Increase down pressure until rotation binds and then back off until rotation and pressure become smooth.
	Damaged Percussion Bit Splines	Check percussion bit splines for damage; repair or replace
Tapered wear on Drive Sub Splines	Not enough down force	Increase down pressure until rotation binds and then back off until rotation and pressure become smooth.
	Percussion Bit splines burred	Check percussion bit splines for damage; repair or replace.