ABOUT BREAK-IN

By Kevin Cameron

The break-in of a new snowmobile has long been an area of great mystery and controversy to most snowmobilers. Do you break it in fast, slow or in normal operation? What actually happens during break-in? Is it really as critical as many make it out to be? To answer all of these questions and more we called upon renowned engine guru Kevin Cameron to explain and demystify the break-in phase of your new snowmobile. Enjoy the read.

What actually happens?

No matter how precisely made the parts of a machine may be, the final machining operation in their manufacture is their first hours of operation, as parts wear subtly to a good mutual fit. Seen under a microscope, or imaged by a profilometer, machined surfaces are seen to have a profile of peaks and valleys – the result of metal-removal operations in production. This minor roughness is worn away during break-in. Piston rings and cylinders – never perfectly round – wear into intimate contact to achieve a good seal. (photo 1)

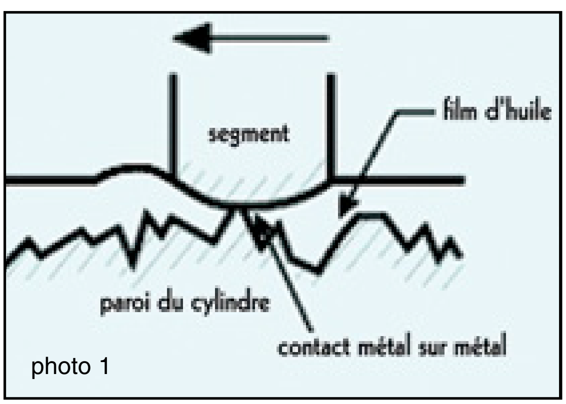


photo 1

Thirty ye a rsago, break-in was a more crucial operation than it is today. The reason is that more metal removal took place in the days when iron cylinders were finished to a coarse 80-grit cross-hatch finish. That finish made the cylinder into a cylindrical double-cut file, which in the first period of operation physically shaved simple cast-iron piston rings into conformity with the cylinder. Once the surface profiles of rings and cylinders had worn down below the operating oil film's thickness, this action ceased and break-in was complete. Thereafter, the oil film would support the rings through most of their travel, reducing wear to a low value.

Today, for a variety of reasons, cylinders are generally finished to a much finer surface profile – often to a 600-grit "plateau" finish (photo 2) – while piston rings are pre-lapped in round cylinders during manufacturing to make them more truly circular. In effect, modern manufacturing has taken upon itself much of the final surface finishing that used to be left to break-in. As a result, break-in today generates less heat and removes less metal than formerly.

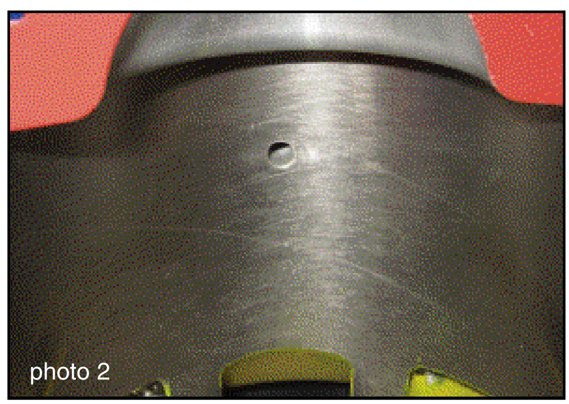
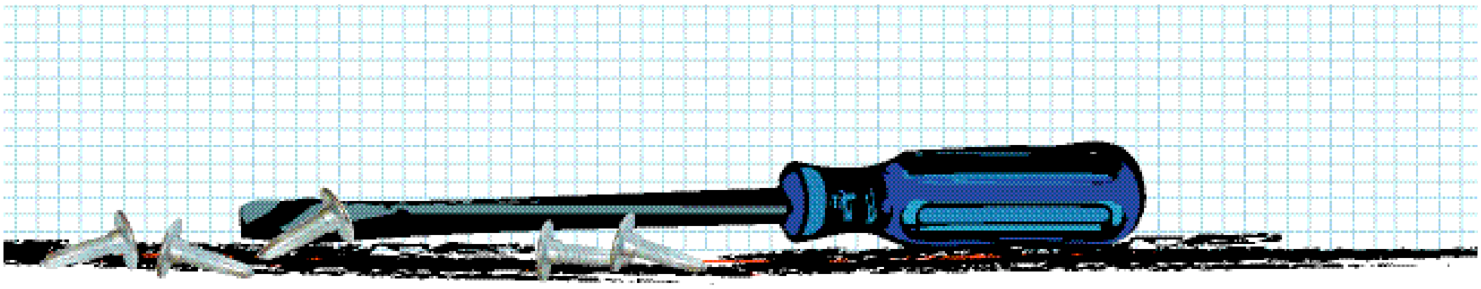


photo 2

Unfortunately, and for an entirely other class of reasons, break-in today can still fail occasionally, as I shall discuss below.

Any time there is actual moving contact between the surface profiles on two machine parts, heat is generated. This is why we are generally advised to vary engine speed and load during break-in. A steady speed and load allows no time for excess heat to dissipate, and no opportunity for changed conditions to sweep away wear particles.



The major goal of break-in is a good, durable piston ring seal. If the ring is overheated in the process, it can lose tension or warp. The better the ring/cylinder fit, the more easily it can be effectively lubricated so it can achieve a long wear life.

When break-in fails, the commonest result is a poor seal. You can see the cause on the wear face of the ring. When properly broken in, you see a continuous band of wear, beginning at the ring's lower edge, extending without breaks all the way around the ring. If break-in fails, this wear pattern is replaced by a succession of shiny spots around the ring face's bottom edge. The spots are the places that have made initial contact, but the wearing-in process stopped before wear produced full contact all the way around the ring. What has happened is that the oil has somehow been able to carry the pressure of the ring on the reduced area of these spots or zones. Between them, leakage takes place. This can be seen by a compression test or leak-down test. When four-stroke piston rings fail to break in, oil consumption remains high and smoke may even be seen from the exhaust.

Another type of break-in failure is scuffing. In this case, either the piston ring or piston make such heavy, prolonged contact with the cylinder wall that lubrication breaks down and parts are damaged, leaving visible marks on the parts and making bore sealing impossible (photo 3). The obvious cause here is too much heat, too early – another reason to observe the above-mentioned alternation between heavy load and periods of low load or coasting.

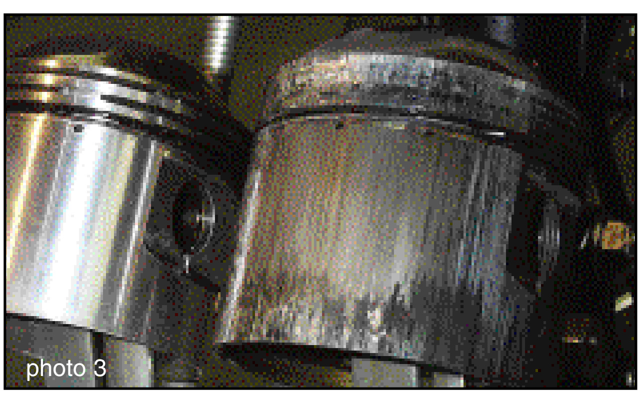


photo 3

A special two-stroke problem is the concentrated load on piston rings at the edges of the exhaust ports (photo 4), which often makes a permanent line or score on the ring face. This usually occurs when a fresh cylinder bore is put into operation without smoothing or radiusing of the port

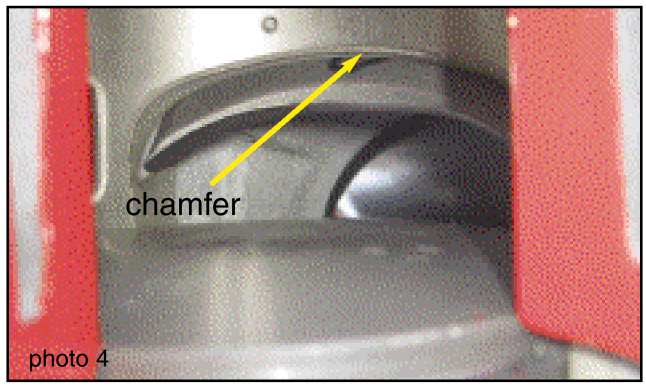


photo 4

edges – an important step. Production parts are usually OK in this respect, but cylinders freshly bored or coated may need port edges smoothed with an abrasive-charged rubber wheel.

THE LORE OF BREAK-IN

This brings us to break-in lore. There are two general myths of break-in, each of which contains elements of truth. The classic, coming down to us from the earliest days, is the "baby it" theory, which tells us to operate our machine only very slowly at first, and gradually increase throttle and rpm use over a period of hundreds of miles.

This theory was correct in 1935, when break-in had to remove large amounts of metal and generated considerable heat in the process. A gradual build-up of load and rpm allowed this metal and heat to be handled without ill consequence.

Why is this not true today? Both parts finishing and oil quality have improved a great deal in seven decades. Oil was just oil in 1935, but at present lubricating oils are heavily loaded with effective anti-wear additives such as

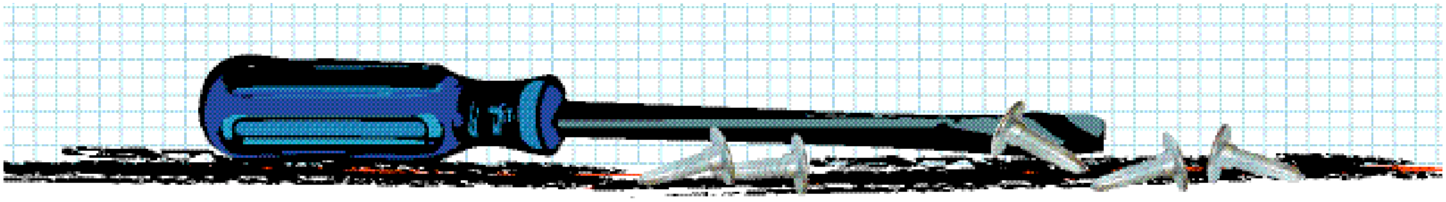


photo 5

zinc dialkyl dithiophosphate (ZDDP). These additives (photo 5) are highly effective in extending engine life – but they can also interfere with break-in by enabling small wear areas to carry heavy loads. Oil additives, more than any other cause, are responsible for the occasional failures of break-in seen today.

Anti-wear additives work by forming durable but fairly slippery solid layers on metal surfaces. When high local pressure damages such layers, they reform from additives carried in the oil. Therefore, if break-in must remove significant metal, it is likely that such additives will stop the process as soon as the load can be carried by the additive layer on a very limited surface area. This is why a piston ring that has failed to break in will show only localized areas of cylinder wall contact – not a 360-degree wear band as it should.

The other leading break-in myth says, "Break it in fast and it'll be fast. Break it in slow and it'll always be slow." This theory came into being during the era of early anti-wear oil additives, which began in the later 1950s. As described above, if an engine requires significant metal removal to complete break-in, and if the oil used contains an anti-wear additive, "babying" the engine during break-in will allow the additive to carry the load before a full piston ring contact is achieved. It is for this reason that many engine manufacturers suggest short periods of fairly heavy throttle, interrupted by periods of light throttle. A representative of a Diesel engine piston ring manufacturer told me that in their experience at least 70% of full load is necessary to achieve piston ring break-in.

There is, however, a difference between "hard", meaning heavy throttle, and "fast", meaning high rpm. Break-in, where anti-wear additive is present, requires significant use of the throttle, but the higher the rpm, the greater the heat generated. It is pressure and not speed that forces piston rings through the anti-wear additive layer to achieve the contact necessary to achieve full break-in.

Widely used in the two-stroke world is "heat cycling" – making several warm-ups and cool-downs before using an engine at heavy loads. While the theory suggests that the parts will somehow relax from heat to accommodate each other, the low throttle used in heat cycling probably doesn't get pistons hot enough to "move". Creep of metals under heat and load requires that the part be at .4 - .5 times its melting point – pretty hot! Therefore I suspect that heat cycling is just another way of making sure an engine is thoroughly warmed up before use.

photo 6

Occasional trouble with break-in is not limited to our own era, although many associate it specifically with synthetic oils. The 1930s were the Golden Age of air racing, when old-timers swore by the oil proven in combat in World War One – castor oil. The oil companies, on the other hand, were pushing the then-new mineral aviation oils. In some cases, engines failed to break in on castor oil.

In four-stroke piston ring testing, a blow-by meter (rather like a city gas meter) is used to measure the volume of gas reaching the crankcase (photo 6). When the engine is brand new, blow-by rate is high, but in a normal break-in quickly falls by half. More than one experienced dyno operator has confirmed to me that break-in is often slowed or even stopped by use of synthetic oils.

Is synthetic oil the problem? (photo 7) Other evidence suggests not – that in fact the problem is the high loadings of anti-wear additive commonly present in modern oils. Vintage engines being rebuilt today often fail to break in, using parts and methods which worked in the past. What has changed is the oils available.

Why have oils changed? In the case of four-stroke oils, I believe that when smaller, higher-revving four-valve auto engines became widespread in the 1980s, some cam and tappet scoring took place because of increased valve acceleration rates. Oil manufacturers solved the problem by adding more anti-wear additive. That led to the 1980s epidemic of new engines whose oil consumption remained high – a result of incomplete piston ring break-in. That, in turn, led to today's "pre-lapped" piston rings and finer bore finishes – both of which reduce the amount of metal that break-in must remove.

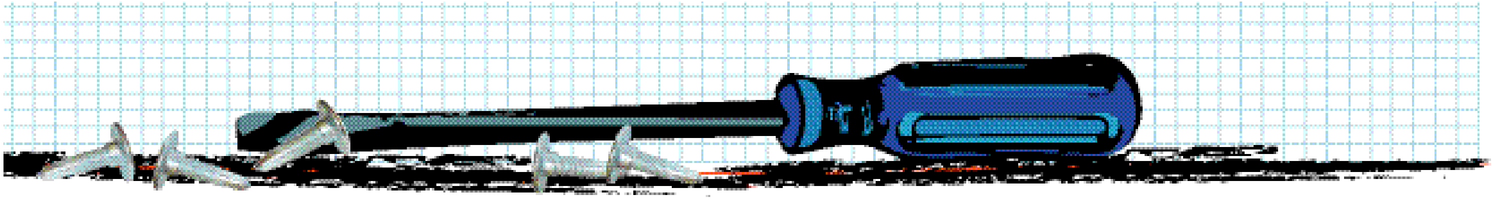


photo 7

Today, new four-stroke engines are essentially pre-broken-in from the factory. Only a short period of break-in is required – really more of an observation period.

If you must break in a rebuilt engine from an earlier period, various techniques exist. First, some oil makers (Motul is one example) offer special break-in oil, compounded without the heavy modern loading of anti-wear. Break in the engine on this special oil, then drain and replace with whatever oil you plan to use in service. Note that four-stroke oil containers carry a code such as 'SG' or 'SH', in addition to the viscosity information such as '10W40'. This code specifies the test standards this oil meets. The 'S' stands for 'Spark', meaning the oil is intended for use in spark-ignition engines. A 'C' indicates the oil is for Compression-ignition use. An 'SA' oil is essentially additive-free, and can be used where a break-in oil is desired.

Second, there is the time-honored method of short periods of heavy throttle, interrupted by periods of coasting during which generated wear particles are swept to the filter by the oil system, and any local heat concentrations can dissipate.

Third, some engine builders employ the so-called "dry break-in" technique. After cylinder walls are washed for assembly, they are wiped clean and dry with paper towels. During assembly, each piston skirt is lubricated with a drop of oil, but the rings are assembled without lubrication. When the engine is initially started, it is brought to half of red-line rpm and held there for 30 seconds. Then the oil and filter are changed.

TWO-STROKE VERSUS FOUR-STROKE

The big difference between two-stroke and four-stroke engines during break-in is that two-strokes have very high piston temperature, naturally caused by their double firing rate. This introduces the possibility of a so-called cold seizure (photo 8) from a piston that has quickly expanded right after start-up to become bigger than its cooler cylinder. When a two-stroke is first started, its pistons heat up much faster than do its cylinders, and with close clearances a seizure is possible even if the clearance is sufficient for full power when fully warmed-up. This makes it desirable to warm up any two-stroke engine before applying any heavy load, even if it is already well broken-in. It is for this reason that some two-stroke makers include a 'slow-running' period in their engine control, during the first hours of new operation.


photo 8

Some two-stroke owners have mixed some oil into their fuel during break-in, reasoning that extra oil means extra protection. If you do this, consider that adding oil to fuel makes the fuel mixture leaner. How? Only those parts of the fuel mixture which are in the form of vapor will burn. All the rest - fuel still in droplet form, and non-volatiles such as lubricating oil - pass through the engine in only partly-burned form. This naturally means that adding oil to the fuel leans out the mixture, as the evaporated fuel has been reduced by the percentage of oil added. For main jets in the 300 range, adding three per cent oil to the fuel is the same thing as jetting down one size. So be forewarned and proceed with caution so as not to create au unduly lean condition which could result in a piston seizure. Again, it is wise to follow the manufacturer's advice.

A lot of information circulates among engine users, not all of it useful to owners of stock equipment. One example is that some NASCAR engine builders replace crankshaft bearing inserts after break-in. This is to avoid crank scoring (photo 9) from wear particles that have embedded in the bearing surfaces. You may also hear of concerned operators using a special "opener" to remove the metal canister from a used oil filter, so that the particle side of the filter surface can be examined. Aircraft engine mechanics are always "looking at the screens" to see if a given engine is "making metal". These are real concerns in the case of engines called upon to give continuous high power, but are unnecessary for users of production machinery. Follow the instructions in your snowmobile's

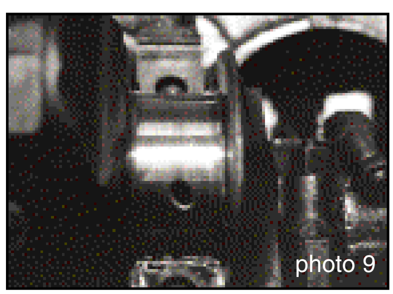
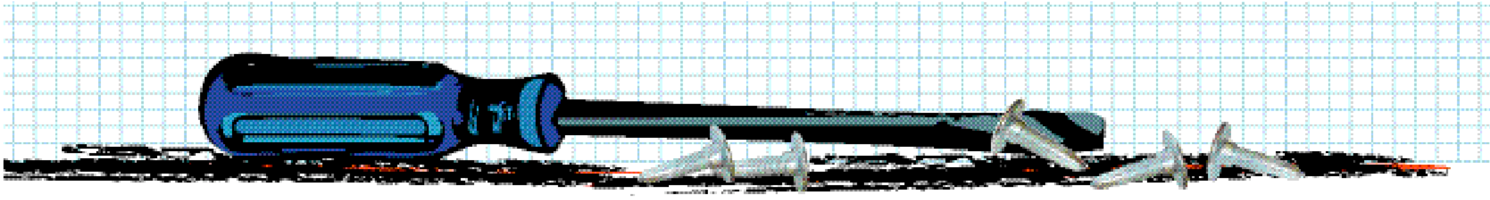
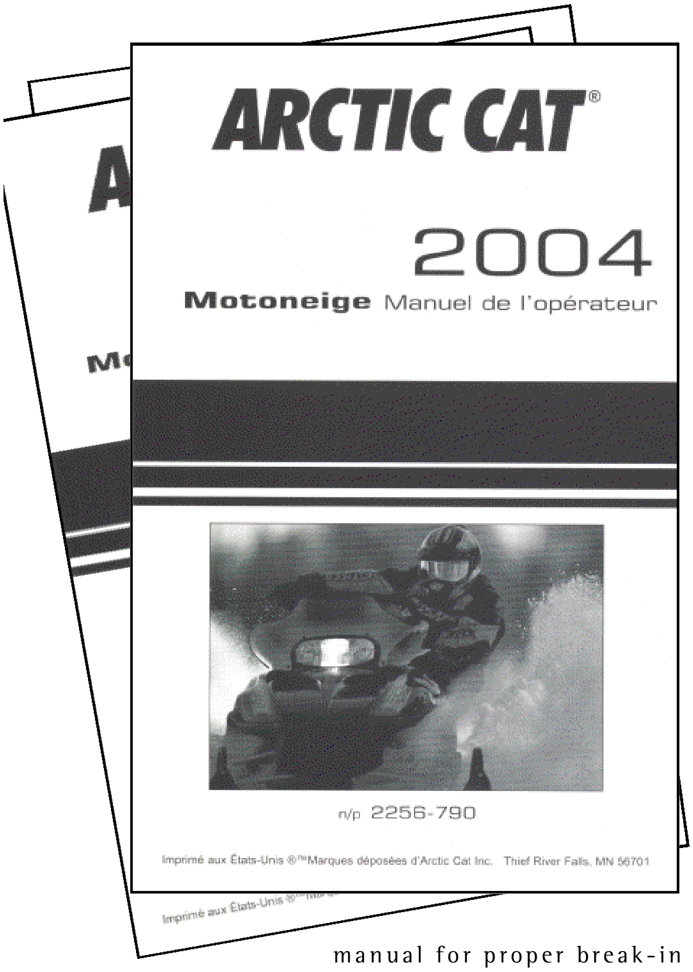


photo 9





manual for proper break-in technique and for correct oil viscosity, type and, in the case of four-strokes, oil change interval. Modern engines are so civilized that they otherwise take care of themselves.

HARD-SURFACED RINGS OR CYLINDERS

As the specific power of engines has increased, the face temperature of piston rings has risen. Long ago, simple cast-iron rings were adequate, but at higher temperature, wear became unacceptably rapid. This led to chromium-plating of piston ring faces. The chrome, whose melting temperature is high, less easily forms an alloy with cylinder wall material when lubrication breaks down, so there is less welding and plucking, and so less wear. Iron is brittle, so steel rings have been adopted to avoid breakage. Even higher temperature conditions may call for rings whose faces are coated with either molybdenum or ceramic. Because each of these materials is harder than the previous, finer initial cylinder wall and ring surfaces are necessary because so little wear takes place.

Alternatively, the hard material may be placed on the cylinder wall, as in the recent shift to Nikasil and other hard coatings, applied directly to the aluminum of the cylinder. This allows the extra weight of iron liners to be avoided, and improves heat dissipation, but at the cost of no longer being able to rebore cylinders for oversize pistons. Whether hard material is applied to the rings or to the bore, higher surfaces finishes are necessary because so little metal removal takes place in break-in.

ENGINE BEARINGS

As is the case with rings and cylinders, crankshaft journals and bearings are now manufactured and gauged to very fine finish and tolerance. This is equally true of two-stroke rolling-element cranks and four-stroke plain journal bearings. As long as there is lubricant present at the moment of start-up, these components now need almost no break-in. In the long-ago past, when a new marine engine was run for the first time, a lad was detailed to monitor bearing temperatures by putting his hand on the journal caps, one after another. If a hot journal developed, the engine would be shut down, the cap removed, and a fitter would carefully scrape down the high spots and try again. Modern manufacturing makes quaint history of all this.

FINAL WORD

Thirty years ago, engine break-in was attended by the generation of much black particulate matter, showing how much metal removal was taking place. Today, higher engine temperatures have made it necessary to employ either hard-faced piston rings or to surface cylinders with highly wear-resistant materials. Because such hard materials wear so slowly, it has been necessary to greatly increase the accuracy of manufacture of piston rings and cylinder bores. The result is engines that require less break-in. Even so, to be on the side of safety it is desirable to closely follow the break-in instructions provided in owners' manuals. A lot happens in the first hours of a new engine's life. A proper break-in will pay dividends throughout the life of your engine so be patient and do it right. Your engine will thank you for it.

Next issue :
We will be taking an in-depth at the revolutionnary SnowHawk 600 HO by AD Boivin. Not to be missed!